



DEPARTMENT OF THE ARMY
U.S. ARMY ABERDEEN PROVING GROUND
ABERDEEN PROVING GROUND, MARYLAND 21005-5001

November 21, 2003

REPLY TO
ATTENTION OF

Directorate of Safety,
Health and Environment

Mr. Frank Vavra
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, Pennsylvania 19103

Dear Mr. Vavra:

Enclosed for your information are two copies of the document entitled, Bush River Study Area, Northern Bush River Remedial Investigation Report, November 2003.

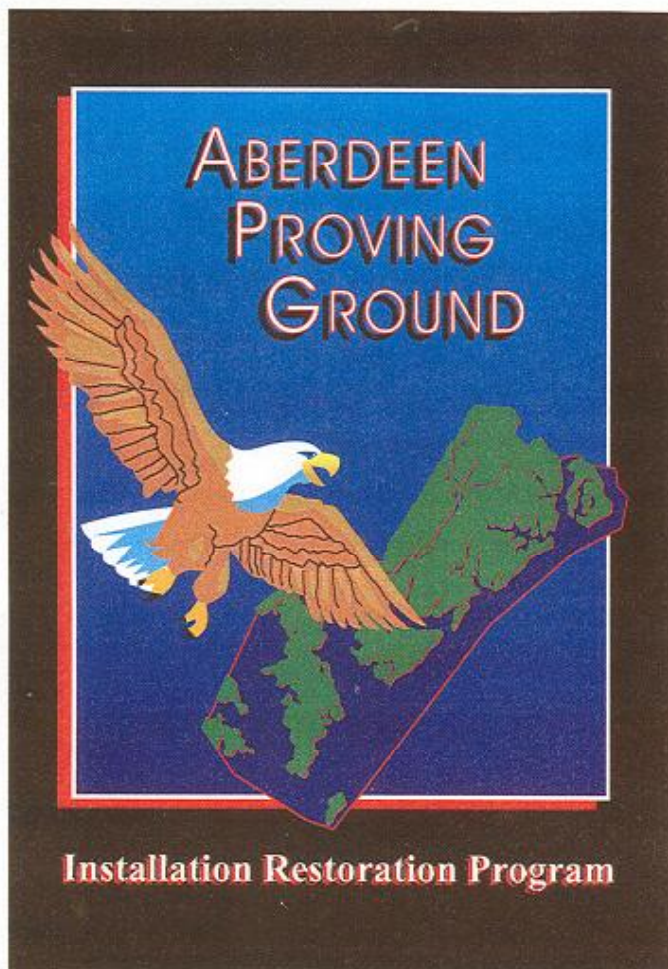
If you have any questions or comments concerning this document, please contact Mr. Don Green, Environmental Conservation and Restoration Division, 410-436-7313.

Sincerely,

A handwritten signature in blue ink, reading "Kenneth P. Stachiw".

Kenneth P. Stachiw
Chief, Environmental Conservation
and Restoration Division

Enclosure



BUSH RIVER STUDY AREA

Northern Bush River RI Report, Volume I

Final
November 2003

U.S. Army Garrison
Aberdeen Proving Ground, Maryland

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14. ABSTRACT The Northern Bush River Remedial Investigation Report, Volume I, documents the site background, technical approach, results of additional environmental investigations, and baseline human health and screening-level ecological risk assessments, completed for nine sites in the Bush River Study Area of the Edgewood Area at the U.S. Army Garrison Aberdeen Proving Ground, Maryland. The document provides the data and rationale for recommending future actions at the Cluster 7 Boat Club Fill Sites (EABR07-A and -B), Cluster 35 Directorate of Public Works Storage Areas (EABR35-A and -B), and portions of the Cluster 36 Warehouse Sites (EABR36-A and -B). Volume II presents the Baseline Risk Assessment.					
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FINAL
BUSH RIVER STUDY AREA

**Northern Bush River
Remedial Investigation Report**

Prepared For:

**U.S. Army Garrison, Aberdeen Proving Ground
Directorate of Safety, Health and Environment
Aberdeen Proving Ground, Maryland**

**Contract No.: DAAD-05-97-D-7003
Delivery Order No.: 0038**

Prepared By:



**General Physics Corporation
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U.S. Army Garrison,
Directorate of Safety, Health and Environment
Aberdeen Proving Ground, Maryland

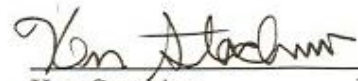
BUSH RIVER STUDY AREA

Northern Bush River
Remedial Investigation Report

November 2003

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LIST OF ABBREVIATIONS AND ACRONYMS

AEC	U.S. Army Environmental Center (formerly USATHAMA)
APG	U.S. Army Garrison, Aberdeen Proving Ground
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BTAG	Biological Technical Assistance Group
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CC2	N,N'-dichloro-bis(2,4,6-trichlorophenyl)urea (a military clothing impregnate)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHPPM	U.S. Army Center for Health Promotion and Preventive Medicine (formerly USAEHA)
CLP	Contract Laboratory Program
CN	chloroacetophenone (a tear gas agent)
COMAR	Code of Maryland Annotated Regulations
COPCs	chemicals of potential concern
CS	ortho-chlorobenzalmalononitrile (a tear gas agent)
4,4'-DDD	dichloro-diphenyl-dichloroethane
4,4'-DDE	dichloro-diphenyl-dichloroethylene
4,4'-DDT	dichloro-diphenyl-trichloroethane
DDTr	sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT
DIMP	diisopropylmethylphosphonate
DIO	APG Directorate of Installation Operations (formerly DPW)
DMMP	dimethylmethylphosphonate
DO	dissolved oxygen
DNAPL	dense non-aqueous phase liquid
DPW	APG Directorate of Public Works
DSHE	APG Directorate of Safety, Health and Environment
DSERTS	Defense Sites Environmental Restoration Tracking System
ECBC	U.S. Army Edgewood Chemical and Biological Command
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center (now ECBC)
FFA	Federal Facility Agreement
GB	sarin (nerve agent)
GD	soman (nerve agent)
GP	General Physics Corporation
HE	High Explosives
HI	Hazard Index
IM	Incendiary Munitions
IMPA	isopropylmethylphosphonic acid
IRP	Installation Restoration Program
LNAPL	light non-aqueous phase liquid

LIST OF ABBREVIATIONS AND ACRONYMS (continued)

MCAWW	Methods for Chemical Analysis of Wastewater
MDE	Maryland Department of the Environment
Ma	Million Years Ago
mg/Kg	milligrams per Kilogram
mg/L	milligrams per Liter
MPA	methylphosphonic acid
msl	mean sea level
NAPLs	non-aqueous phase liquids
NTUs	Nephelometric Turbidity Units
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
pCi/g	picoCuries per gram
pCi/L	picoCuries per Liter
ppb	parts per billion ($\approx \mu\text{g/L}$ or $\mu\text{g/Kg}$)
ppm	parts per million ($\approx \text{mg/L}$ or mg/Kg)
QA/QC	quality assurance/quality control
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RI/FS	Remedial Investigation/Feasibility Study
SOPs	Standard Operating Procedures
STEP	Solutions To Environmental Problems, Inc.
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TCPU	sym-bis(2,4,6-trichlorophenyl)urea (a military clothing impregnate degradation compound)
TOC	total organic carbon
TPH	total petroleum hydrocarbons
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center (formerly USATHAMA)
USAEHA	U.S. Army Environmental Hygiene Agency (now CHPPM)
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency (now USAEC)
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
UXO	unexploded ordnance
$\mu\text{g/Kg}$	micrograms per Kilogram
$\mu\text{g/L}$	micrograms per Liter
VOC	volatile organic compound
VX	(an organophosphorus, persistent nerve agent)

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EXECUTIVE SUMMARY

The Northern Bush River Remedial Investigation Report presents the site background, technical approach, results of environmental field studies and laboratory analyses, Baseline Risk Assessment, and recommended remedial action objectives for sites associated with the Cluster 7 Boat Club Fill Sites (EABR07-A and -B), Cluster 35 Directorate of Public Works Storage Areas (EABR35-A and -B), and portions of the Cluster 36 Warehouse Sites (EABR36-A and -B) within the Bush River Study Area of the Edgewood Area at the U.S. Army Garrison, Aberdeen Proving Ground, Maryland. The Cluster 3 Old Bush River Road Dump Sites and Southern Bush River (i.e., Clusters 11, 18, 15, and the remaining portion of Cluster 36) are addressed by separate Remedial Investigation reports. The Remedial Investigation was conducted in accordance with the regulations and guidance developed by the U.S. Environmental Protection Agency pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act as amended by the Superfund Amendments and Reauthorization Act. The Aberdeen Proving Ground Directorate of Safety, Health and Environment, Environmental Conservation and Restoration Division conducted the investigation under the direction of the U.S. Environmental Protection Agency Region III and Maryland Department of the Environment, following the terms of Aberdeen Proving Ground's March 27, 1990, Federal Facility Agreement. The Federal Facility Agreement mandated further investigations due to the Edgewood Area's inclusion on the U.S. Environmental Protection Agency's National Priorities List on February 21, 1990.

The Bush River Study Area covers approximately 500 acres on a peninsula located in the northeastern portion of the Edgewood Area, and is bounded on the north by Lauderick Creek, on the east and south by Bush River, and on the southwest by Kings Creek. Since the early 1930s, the 230-acre area of Northern Bush River has been used for general storage, chemical storage, and waste disposal under a military industrial land use setting. The U.S. Army primarily used this area of the peninsula as a storage facility for different types of materials used in research, testing, and production operations in the Edgewood Area. Such materials included chemical agents (i.e., tear gas agents and materials for production use), general storage items, munitions, and high explosives. Since the 1950s, portions of the area have been used for open storage of bulk, construction-related materials (e.g., gravel, soil, crushed stone, and salvaged building supplies). The Northern Bush River Area contains six listed sites from the 319 solid waste management units identified in the 1989 Resource Conservation and Recovery Act Facility Assessment, and 1992 Generic Work Plan, and three areas of concern identified during the Remedial Investigation.

The Remedial Investigation served as the mechanism for collecting data to characterize site conditions, determine the nature and extent of contamination, evaluate contaminant fate and transport, and assess potential risks to human health and the environment. The work included

passive soil gas surveys of 198 points; installation of 19 groundwater monitoring wells; removal actions; and a multimedia sampling program consisting of 19 groundwater, 13 surface water, 14 sediment, 30 surface soil, 8 subsurface soil, and 2 sludge water locations. Chemical analyses were performed on one round each of soil, sediment, and sludge water samples; two rounds of surface water samples; and two rounds of groundwater samples. Samples were analyzed for the presence of organic contaminants on the Target Compound List, inorganic contaminants on the Target Analyte List, chemical agent degradation products, explosive-related compounds, radiological analytes, and general chemical constituents. In addition, a wetland delineation of the study area was completed to further define the wetland areas.

The Remedial Investigation identified environmental media contamination within localized or limited portions of the sites. Sporadic and isolated detections of volatile organic compounds, pesticides, and inorganic analytes (e.g., arsenic and iron) were detected in groundwater and surface water. Concentrations of semi-volatile organic compounds (e.g., polycyclic aromatic hydrocarbons) and pesticides occurred in sediment and soil associated within some sites. No polychlorinated biphenyls, explosive-related compounds, or chemical agent degradation compounds were detected in Northern Bush River environmental media. Both the chlorine contact chamber of the wastewater package treatment plant associated with the Cluster 7 former Bio-Sensor Research Facility and the septic tank associated with the Cluster 36 Building E2169 serve as a potential source of contamination. Both of the unused, septic tank systems are in close proximity to surface water, and metal concentrations in the underground tanks exceeded background and ecological risk screening levels for surface water.

The human health risk assessment compared the estimated upper-bound excess lifetime cancer risks for the Northern Bush River Area to the U.S. Environmental Protection Agency's target risk range of 1×10^{-6} to 1×10^{-4} for health protectiveness at Comprehensive Environmental Response, Compensation, and Liability Act sites. The estimated, non-carcinogenic hazard indices were compared to 1. Hazard indices greater than 1 indicate a potential for adverse health effects.

Under current, land use conditions, the human health risk assessment evaluated trespasser exposures from dermal exposure of chemicals in surface water while wading at the site-wide marsh areas of Lauderick Creek and Kings Creek, and youth visitor exposures from incidental ingestion and dermal absorption of chemicals in sediment and surface water while swimming in open water areas near the Boat Club Fill Sites. The risk assessment also conservatively evaluated the possible ingestion of chemicals in the groundwater by a hypothetical, future site worker, and excavation worker exposures from incidental ingestion and dermal contact with chemicals in subsurface soil.

The excess lifetime cancer risks associated with site worker ingestion of the groundwater in Clusters

7 and 35 were estimated to be 6×10^{-5} and 4×10^{-5} , respectively, and were primarily associated with total arsenic and beryllium exposures. Estimated cancer risks from the ingestion of Cluster 36 groundwater were not calculated since none of the chemicals of potential concern had available carcinogenic toxicity criteria. The hazard index associated with non-carcinogenic chemicals in each of the three data groupings was equal to 2, and was primarily associated with total iron. Iron concentrations in groundwater were considered to be in reference (background) levels. All other estimated lifetime excess cancer risks and cumulative site risks to individual receptors (i.e., trespasser, youth visitor, and excavation worker exposures), for current and future exposure pathways in the Northern Bush River Area, were within the target risk range for health protectiveness. The hazard indices for all other exposure pathways were less than 1, indicating that adverse non-carcinogenic effects would not be expected to occur.

An attachment to the human health risk assessment summarized risks associated with exposures in Northern Bush River under hypothetical, future residential land use conditions. No chemicals of potential concern with available toxicity criteria were selected in the surface soil data groupings; therefore, the probability of contracting cancer from surface soil exposures would be less than one in one million, and adverse non-carcinogenic effects would not be expected to occur. Potential cancer risks to hypothetical, future child residents from exposures to surface water and sediment would be within the acceptable risk range for health protectiveness, and adverse non-carcinogenic effects would not be expected to occur. For conservative purposes, the attachment used the maximum detected arsenic, beryllium, and iron concentrations from one sample location in a groundwater grouping as the exposure point concentration, resulting in an overestimate of risk for hypothetical, future resident exposures to groundwater. These metal concentrations in groundwater were considered to be within background ranges. In summary, the potential risks associated with hypothetical, future resident exposure pathways were at the low end of the acceptable risk range for health protectiveness, and below levels that would generally warrant remedial action.

The screening-level ecological risk assessment indicated concentrations of mercury exceeded the toxicity reference value for aquatic organism exposures to one surface water sample point; and the pesticide 4,4'-DDT and its degradation compounds exceeded the toxicity reference value for benthic organism exposures to two sediment sample points. Subsequent sampling in 2000 did not find elevated concentrations of mercury in surface water and sediment, and the pesticide 4,4'-DDT and its degradation compounds in sediment. Therefore, no further investigation of these compounds is recommended.

Sufficient data have been collected to complete the Northern Bush River Remedial Investigation, including the human health and screening-level ecological risk assessments. Removal actions of the burned remains of gas mask remnants and contaminated soil north of an entrance gate to the

southern portion of the current secured storage area, potentially contaminated surface waste material throughout the Bush River Study Area, and munitions at one location on the Lauderick Creek shoreline have eliminated the known wastes and removed materials at these sites as contaminant source areas. The possible presence of buried unexploded ordnance and chemical warfare material within the Northern Bush River Area cannot be eliminated based on known historical testing and recent removal of unexploded ordnance and remnants. The U.S. Army has posted signs informing potential trespassers of the dangers present on the site. Additionally, random patrols by military police and other law enforcement officials reduce the likelihood of trespassers. The following recommended future actions are based on the Remedial Investigation and risk assessment results:

- Removal of the metal-contaminated water in the chlorine contact chamber of the wastewater package treatment plant associated with the Cluster 7 former Bio-Sensor Research Facility and the septic tank associated with the Cluster 36 Building E2169, and abandonment of the structures with flowable, concrete fill are recommended to prevent environmental release.
- No further action is recommended for the following nine sites: the Boat Club Fill Sites (EABR07-A); Bio-Sensor Research Facility (EABR07-B); Gravel and Soil Storage Sites (EABR35-A); Buildings E2144, E2148, and E2150 (EABR35-B); Warehouse Storage Areas (EABR36-A); Building 846 (E2194) Waste Disposal Site (EABR36-B); the Drummed Soil Road Barricade Site 26A (EABR36-A); Boat Club Ship Store (Building E2169) (EABR36-A); and the Directorate of Public Works Southwest Storage Areas (EABR36-A).

1.0 INTRODUCTION

This Remedial Investigation (RI) report presents the site background, technical approach, and results of environmental investigations and laboratory analysis completed for Northern Bush River (i.e., Cluster 7 Boat Club Fill Sites, Cluster 35 DPW [Directorate of Public Works] Storage Areas, and the remaining portions of Cluster 36 Warehouse Sites) of the Bush River Study Area at the U.S. Army Garrison, Aberdeen Proving Ground (APG), Edgewood Area, Maryland. The report includes data interpretations, baseline human health and screening-level ecological risk assessments, and recommendations for the future direction of work. The Northern Bush River RI report is organized into the following eight sections:

- Section 1 (Introduction) provides an overview of the regulatory requirements that govern the APG Installation Restoration Program (IRP) and the Remedial Investigation/Feasibility Study (RI/FS) process at the study area. The section presents the purpose and scope of the Northern Bush River RI and summarizes the site history, preliminary assessments, and site investigations conducted at these sites. The section also describes the scoping documents that guide the conduct of the RI.
- Section 2 (Study Area Investigation) addresses the scope of activities performed as part of this RI. The section discusses the rationale for placement of all environmental media sampling locations, field activity procedures, laboratory methods, and protocols.
- Section 3 (Physical Characteristics of Study Area) discusses the physical setting, including regional and local geology, hydrogeology, climate, demography, and ecology in Northern Bush River. This section also characterizes the surface soil, unsaturated zone, and aquifers based on the results of geologic and hydrogeologic studies.
- Section 4 (Nature and Extent of Contamination) assesses the extent of environmental media contamination, presents the approach to the analysis of the RI field investigation results, and summarizes the RI sampling results above the RI comparison criteria.
- Section 5 (Contaminant Fate and Transport) evaluates the fate and transport of sustained and patterned contaminants, and their interaction with the environment at Northern Bush River.
- Section 6 (Baseline Risk Assessment) evaluates potential impacts to human and ecological receptors in Northern Bush River. The human health and screening-level ecological risk assessments screen and identify receptor pathways, and evaluate the level of risk associated with the contamination at Northern Bush River.

- Section 7 (Summary and Conclusions) summarizes the nature and extent of contamination at Northern Bush River based on sampling results and evaluation of potential human health and ecological risks. The section also discusses data gaps and recommendations for future work.
- Finally, Section 8 (References) lists the references used in the preparation of this report.

In addition, the following appendices are provided:

- Appendix A: Data Results, Groundwater
- Appendix B: Data Results, Surface Water and Sediment
- Appendix C: Data Results, Surface Soil
- Appendix D: Data Results, Subsurface Soil
- Appendix E: Data Results, Sludge
- Volume II of the Remedial Investigation Report contains the Baseline Risk Assessment

The Northern Bush River RI was conducted in accordance with the regulations and guidance developed by the U.S. Environmental Protection Agency (USEPA) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act of 1986. The RI was performed in accordance with the following documents: *Draft Final Work Plan, Boat Club Area Fill Sites, Cluster 7, Bush River Area* (U.S. Army Corps of Engineers [USACE], Baltimore District, 1995a); *Work Plan Addendum for the Remedial Investigation at Cluster 7, Bush River Study Area, Edgewood Area, Aberdeen Proving Ground, Maryland* (Earth Tech, Inc. and General Physics Corporation [GP], 1996c); *Detailed RI Work Plan for Cluster 35 of the Bush River Study Area, Edgewood Area, Aberdeen Proving Ground* (GP, 1994b); *Detailed RI Work Plan for Cluster 36 of the Bush River Study Area, Edgewood Area, Aberdeen Proving Ground* (GP, 1994c); and *Generic Work Plan for CERCLA Remedial Investigation/Feasibility Study and Appendix J (Standard Operating Procedures)* (USACE, Baltimore District, 1992).

The APG Directorate of Safety, Health and Environment (DSHE), Environmental Conservation and Restoration Division, manager of the APG IRP, conducted the Northern Bush River RI under the direction of the USEPA Region III and Maryland Department of the Environment (MDE), following the terms of APG's March 27, 1990, Federal Facility Agreement (FFA). The FFA outlines mutual responsibilities regarding APG, and establishes a procedural framework and schedule for developing and implementing response actions in accordance with CERCLA and other

applicable statutes. Under the FFA, the major areas of concern at APG were divided into 13 study areas to aid in IRP investigations. Thus, the FFA expedites the study and cleanup of environmental contamination at APG, and ensures that investigations of past activities result in the initiation of appropriate actions.

In addition to the recommendations in the *Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) for the Edgewood Area of Aberdeen Proving Ground, Maryland* (U.S. Army Environmental Hygiene Agency [USAEHA], 1989) for performing further sampling and analyses at specific sites, the FFA mandated further investigations under CERCLA. The FFA based this requirement on the Edgewood Area's inclusion on the USEPA's National Priorities List on February 21, 1990. DSHE initiated an RI at the Bush River Study Area based on previous site activities that could have resulted in potential environmental contamination.

1.1 Purpose of Report

According to USEPA guidance, the objective of an RI/FS is "to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site" (USEPA, 1988a). Thus, the Northern Bush River RI serves as the mechanism for collecting data to characterize site conditions, determine the nature and extent of contamination, and assess potential risks to human health and the environment. The ultimate goal of the Northern Bush River RI is to collect data for the Baseline Risk Assessment. Specific objectives are as follows:

- Assess potential sources of environmental contamination from listed sites within Northern Bush River and any additional sites discovered during the RI, and evaluate the magnitude and extent of the contamination at each.
- Determine whether contamination from these potential sources is migrating.
- Characterize physical features, including climate, surface and subsurface features, human populations and land use, and ecology.
- Characterize the geology, hydrogeology, and hydrology at the area with respect to the interrelations among the surficial (water table) aquifer, the confined Canal Creek aquifer, Lauderick Creek, Kings Creek, and the Bush River.
- Assess the risks that the potential contaminants could pose to human health or the environment.

- Determine whether data are sufficient to develop and evaluate potential remedial alternatives.

Because only limited site characterization data for Northern Bush River was previously available, the RI has been designed to address all potential sites in the area. DSHE used a phased site characterization approach to systematically evaluate areas within Northern Bush River in accordance with USEPA guidance for conducting an RI (USEPA, 1988a and b). The approach comprised the following eight major components:

- Background characterization of Northern Bush River, including physical characteristics and environmental setting, operations and waste disposal history, summary of previous investigations, and preliminary contamination assessments;
- Soil gas surveys to identify potential areas of volatile organic compound (VOC) contamination and assist in determining additional sampling points;
- Geotechnical and monitoring well borings followed by stratigraphic sampling and headspace analysis to evaluate the potential existence of subsurface VOCs, and provide information on the stratigraphy and hydrogeology in the area;
- Installation, development, and hydraulic testing of groundwater monitoring wells;
- Environmental media sampling (i.e., groundwater, surface water, sediment, soil, and sludge) for characterization of all sites in addition to other investigations;
- Laboratory analysis of environmental media samples and chemical data reporting of detected compounds;
- Evaluation of results from data analysis to characterize each site and to develop the Baseline Risk Assessment; and
- Assessment of site data to determine the necessity of subsequent investigations or refinement of data collection for the evaluation of specific remedial technologies, pilot treatability studies, and long-term contaminant monitoring.

1.2 Edgewood Area Description

APG lies on the northwestern shore of the Chesapeake Bay in southern Harford County and eastern Baltimore County, Maryland (Figure 1-1). Major geographical areas bordering APG include the Chesapeake Bay and its tributaries; Gunpowder Falls State Park; the Crane Power Plant; the towns of Edgewood, Joppatowne/Magnolia, Aberdeen, and Perryman; and various smaller residential

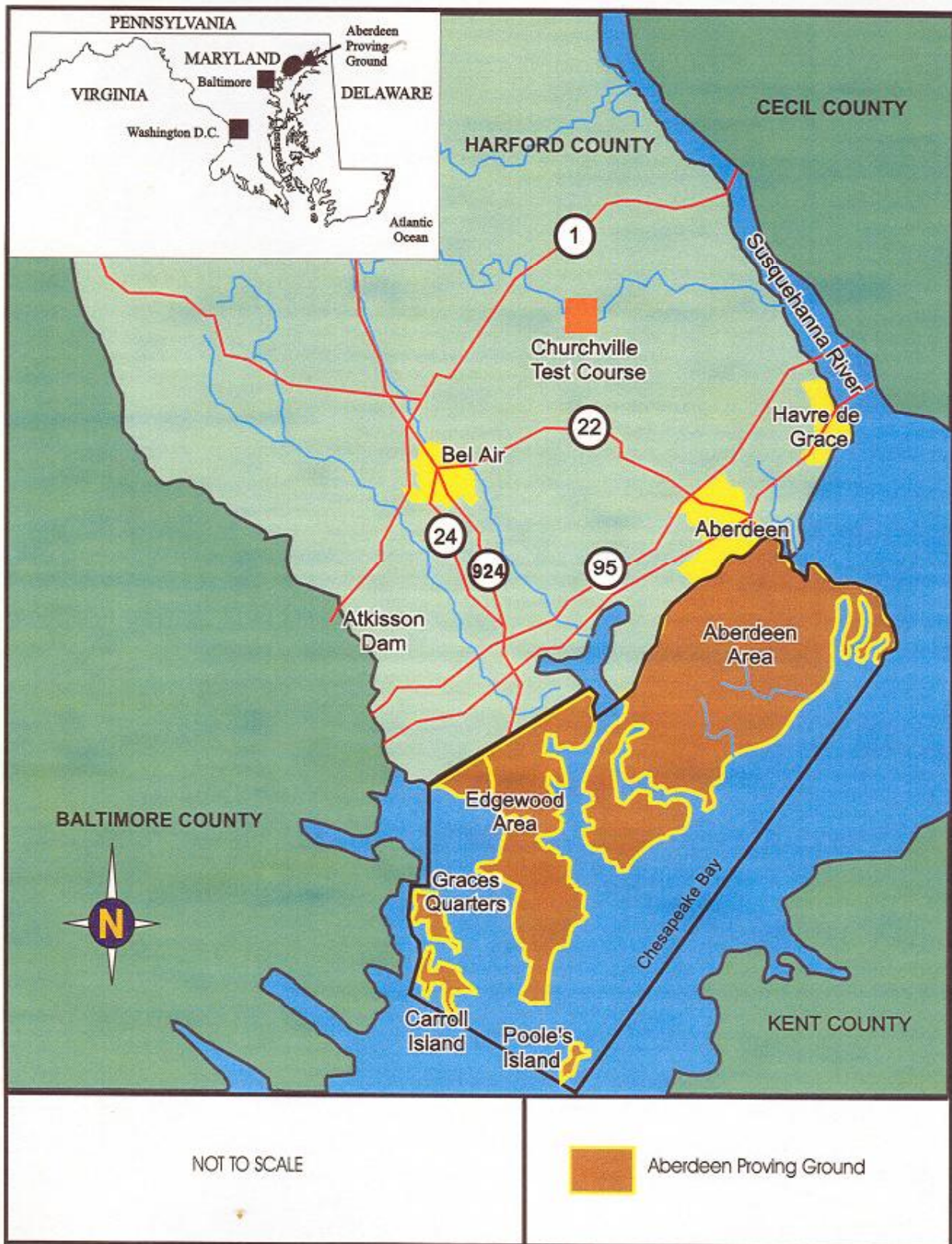


Figure 1-1. Location of APG

areas. APG occupies 79,000 acres of land and water. The Bush River divides the Installation into two noncontiguous areas commonly referred to as the Aberdeen Area and the Edgewood Area.

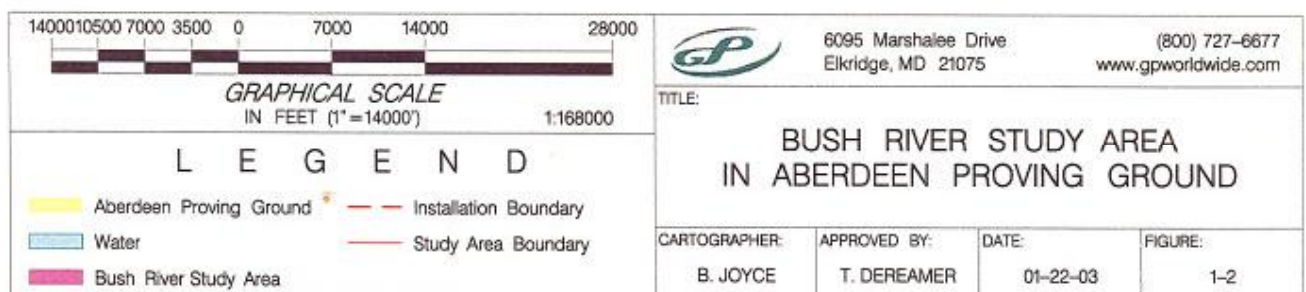
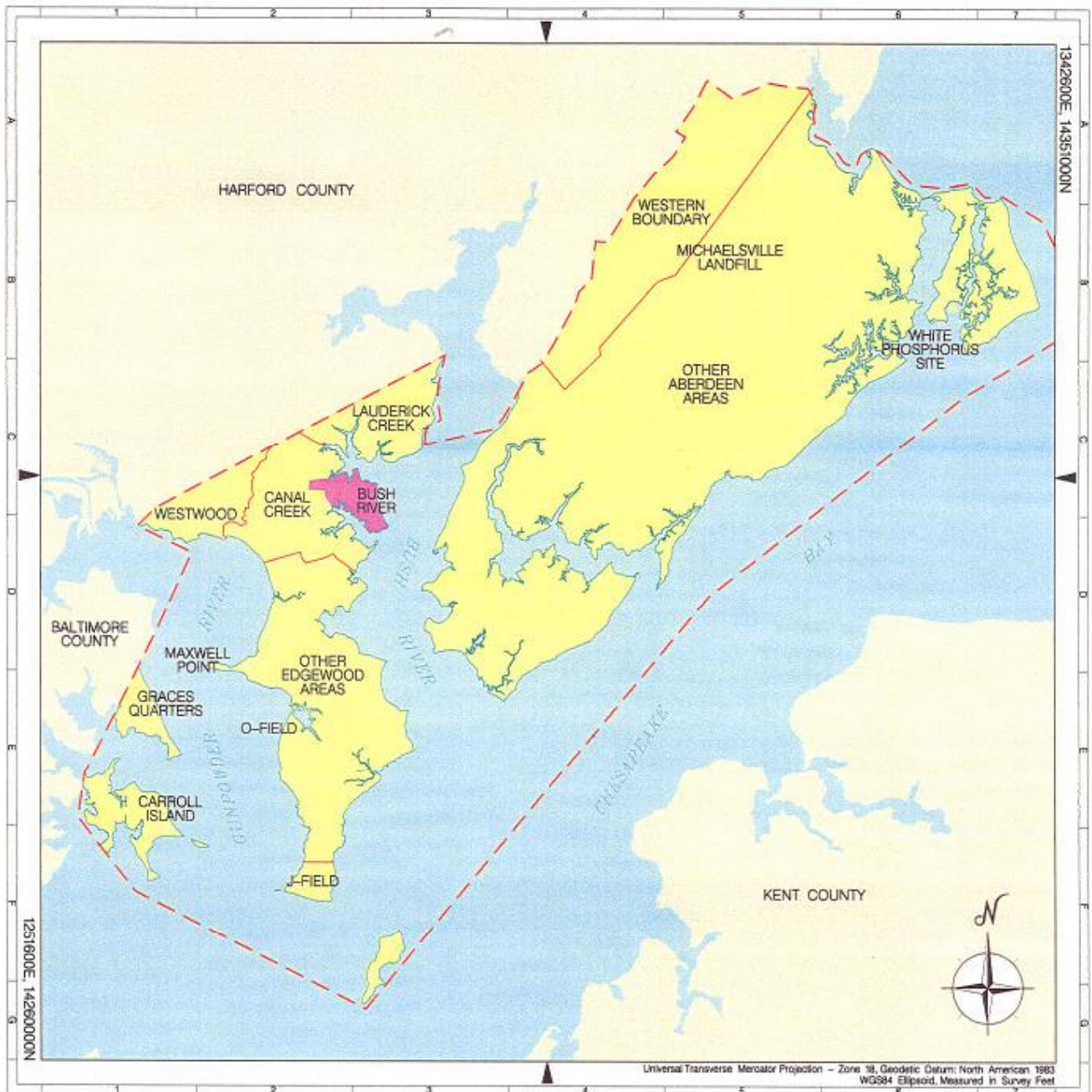
Historically, the Aberdeen Area and Edgewood Area of the proving ground have pursued distinct missions. The Aberdeen Area of the Installation was established in 1917 as a U.S. Army Ordnance Proving Ground and became a formal military post in 1919. A Presidential Proclamation appropriated the Edgewood Area for use in 1917. APG's primary mission is testing and developing weapons systems, munitions, and a variety of support material for military operations (U.S. Army Toxic and Hazardous Materials Agency [USATHAMA], 1976 and 1983). Since 1917, the Edgewood Area has been the center for the research, development, testing, and manufacture of military-related chemicals and chemical agents. Activities at the Edgewood Area have included laboratory research, development, field testing, and pilot- and production-scale manufacture of chemical warfare agents. Chemical warfare materiel, hazardous wastes, and low-level radiological wastes have also been stored at the Edgewood Area (USAEHA, 1989).

1.3 Bush River Study Area Description

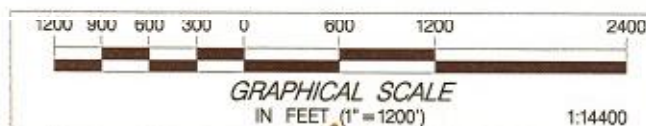
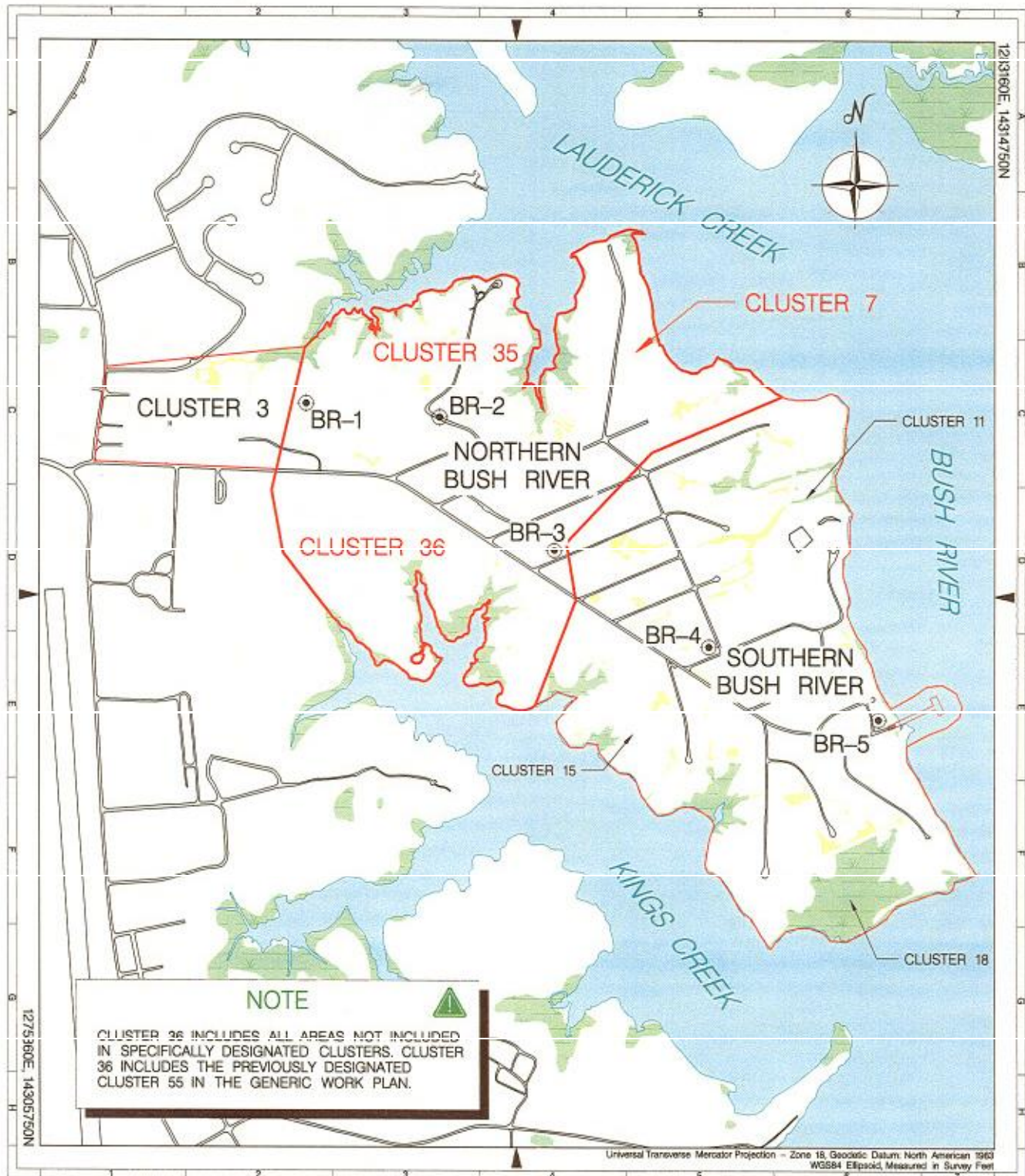
The Bush River Study Area (Figure 1-2) lies in the northeast portion of the Edgewood Area. It encompasses approximately 500 acres on a peninsula bounded to the north by Lauderick Creek, to the east and south by Bush River, and to the southwest by Kings Creek. The study area has low relief, sloping gradually to the south with elevations in the area ranging from zero to 25 feet above mean sea level (msl). It consists of a mixture of wetlands, upland forests, fields, buildings, and roads. The Generic Work Plan divided the entire Bush River Study Area into eight clusters of sites (Figure 1-3) numbered 3, 7, 11, 15, 18, 35, 36, and 55. The APG IRP later incorporated Cluster 55 into Cluster 36 to address all potential receptors, thereby eliminating Cluster 55. The Northern Bush River RI comprises three Bush River Study Area clusters (i.e., Clusters 7, 35, and the remaining portions of Cluster 36). The Cluster 3 Old Bush River Road Dump and Southern Bush River (Clusters 11, 15, 18, and portions of Cluster 36) are addressed by separate RI reports.

1.4 Northern Bush River Description

Clusters 7, 35, and the remaining portions of Cluster 36 comprise Northern Bush River in the central and northern portions of the Bush River Study Area (Figure 1-3). Geographical features bordering the area include Lauderick Creek to the north, Bush River to the east, Clusters 11 and 15 to the south, Kings Creek to the southwest, and Cluster 3 to the west. Military industrial land use encompasses Northern Bush River. The Grant Court and Skippers Point residential communities



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LEGEND

- | | | |
|-------|-------------------|------------------------------|
| Water | Tidal Wetland | Geotechnical Boring Location |
| Road | Non-tidal Wetland | |



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TITLE:

BUSH RIVER STUDY AREA CLUSTER LOCATIONS

CARTOGRAPHER:

B. JOYCE

APPROVED BY:

T. DERAMER

DATE:

01-22-03

FIGURE:

1-3

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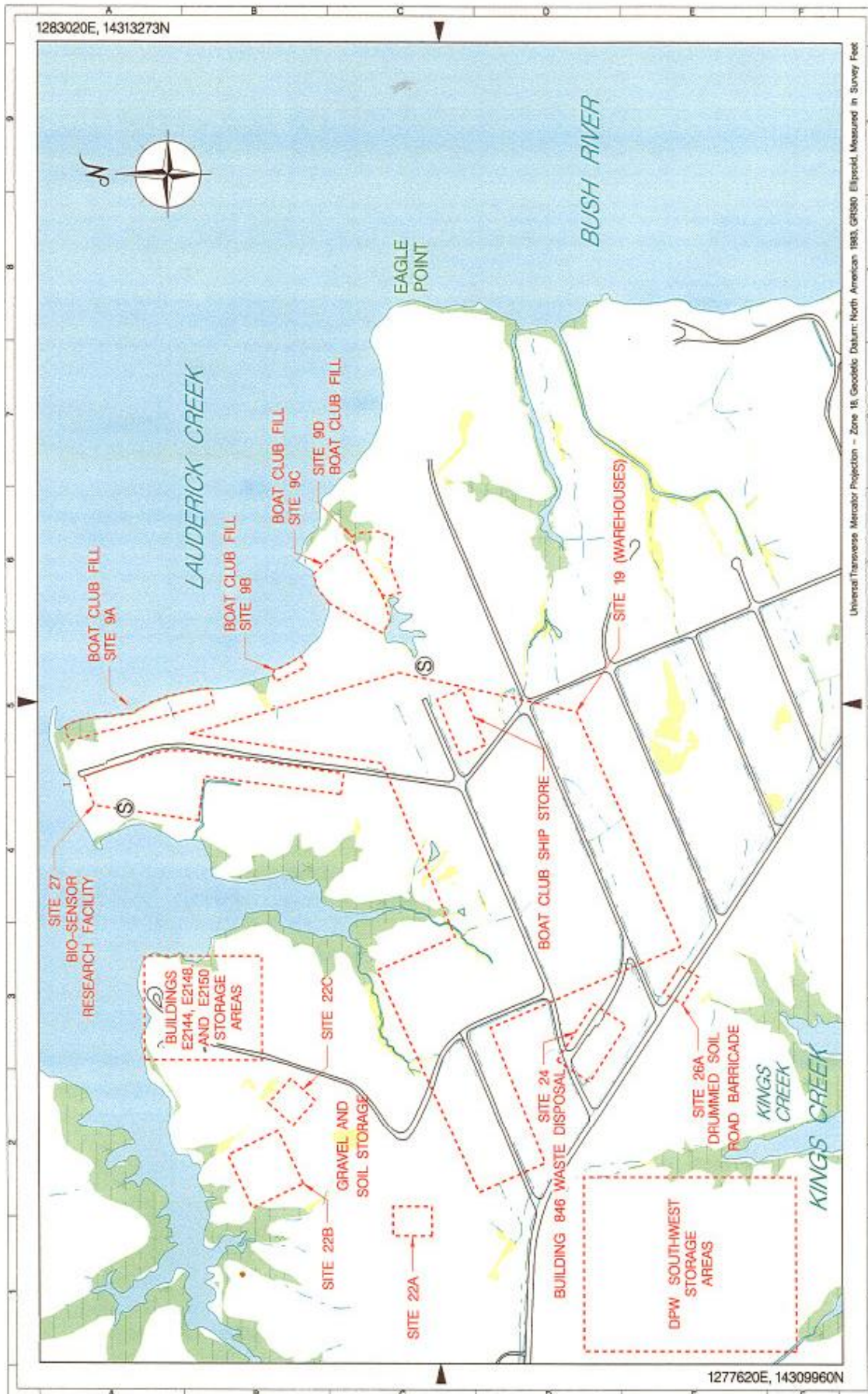
for on-site military personnel lie northwest, and the "3000 Block" of the Clearview Drive on-post residential community lies west of the study area. Northern Bush River contains six of the 28 sites designated in the Generic Work Plan. Sites 9 and 22 consist of separate locations labeled 9A, 9B, 9C, 9D, 22A, 22B, and 22C to allow for a specific discussion. Table 1-1 presents a listing of the sites, including three unnumbered sites identified during the RI. The unnumbered sites are additional areas of concern based on site evaluations and field examinations. Figure 1-4 displays the location of the Northern Bush River sites and features. Figure 1-5 shows an enlarged map of Cluster 7 sites and features. Currently, Northern Bush River consists mostly of buildings and cleared areas with improved (paved) and unimproved (gravel) roads leading to open storage yards, warehouses, and the Boat Club marina, which are surrounded by wooded areas. The southern portion of Northern Bush River is fenced and patrolled, requiring security clearance for access. The maps do not display fences for operational security requirements.

Table 1-1. Northern Bush River Sites

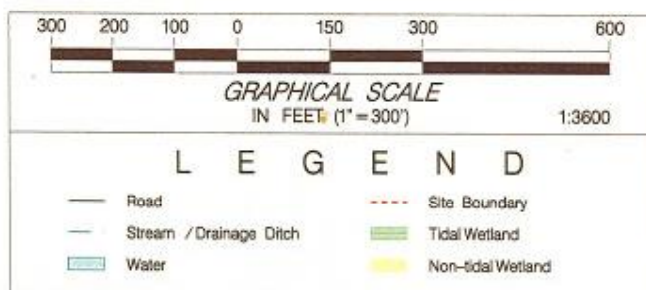
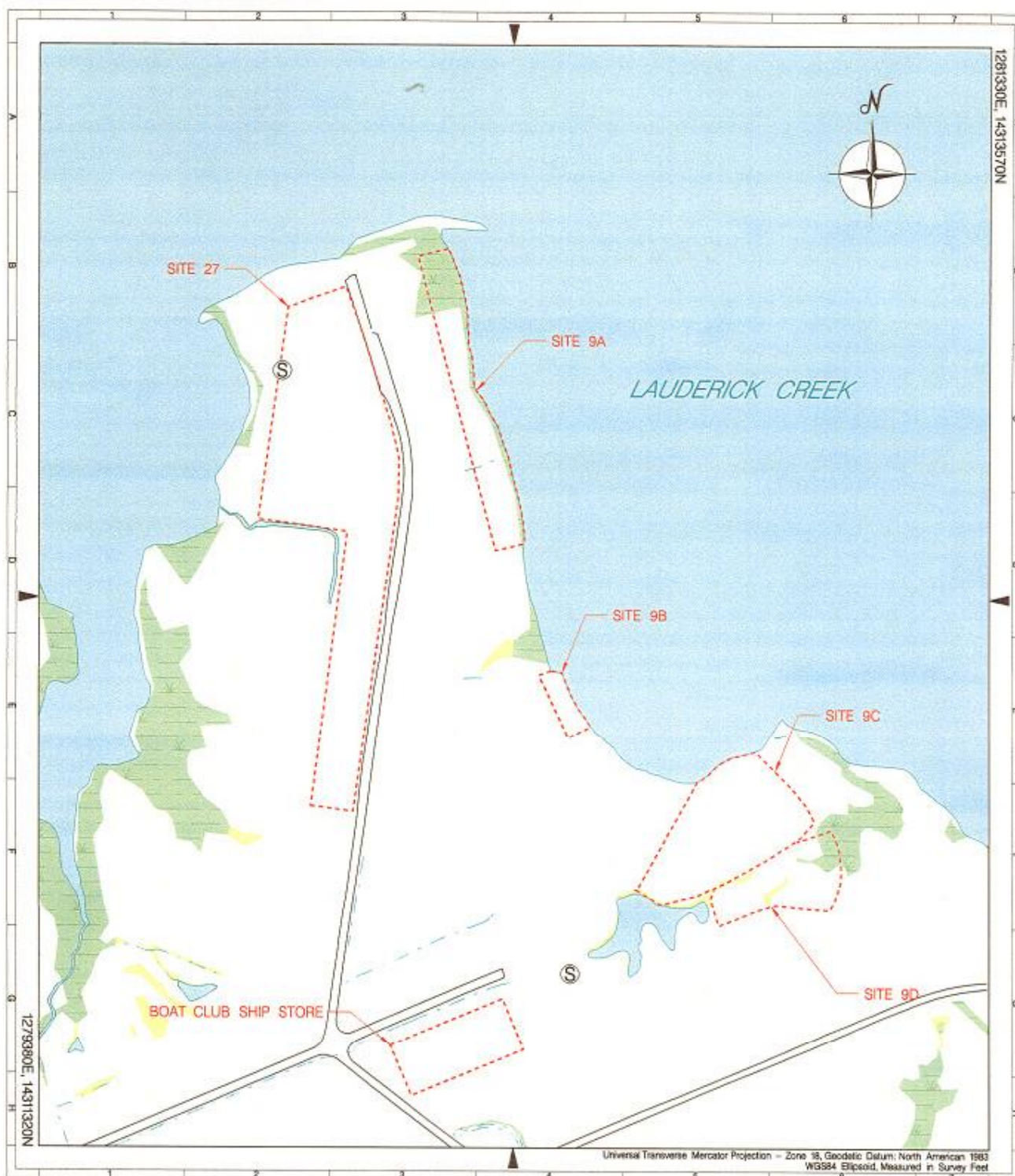
Site Number	Site Name	DSERTS Number
Cluster 7 Boat Club Fill Sites		
9A, 9B, 9C, 9D	Boat Club Fill Sites	EABR07-A
27	Bio-Sensor Research Facility	EABR07-B
Cluster 35 DPW Storage Areas		
22A, 22B, 22C	Gravel and Soil Storage	EABR35-A
Unnumbered	Buildings E2144, E2148, and E2150	EABR35-B
Cluster 36 Warehouse Sites		
19	Warehouse Storage Areas	EABR36-A
24	Building 846 (E2194) Waste Disposal Site	EABR36-B
26A	Drummed Soil road Barricade Site	EABR36-A
Unnumbered	Boat Club Ship Store (Building E2169)	EABR36-A
Unnumbered	DPW Southwest Storage Areas	EABR36-A

Site numbers and names were designated in the Generic Work Plan and Associated Detailed RI Work Plans.

DSERTS – Defense Site Environmental Restoration Tracking System
DPW – Directorate of Public Works



LEGEND Road Stream / Drainage Ditch Septic Tank Site Boundary Water Tidal Wetland Non-tidal Wetland		GRAPHICAL SCALE IN FEET (1" = 600') 600 400 200 0 300 600 1200	TITLE: NORTHERN BUSH RIVER SITES AND FEATURES
6095 Marshalee Drive Elkridge, MD 21075 (800) 727-6677 www.gpworldwide.com		CARTOGRAPHER: APPROVED BY: DATE: FIGURE: B. JOYCE T. DEREMER 01-22-03 1-4	I:\Edgewood Graphics\GEOGRAPHICS\Bush River\Northern Bush River.esdgn



6095 Marshalee Drive
Elkridge, MD 21075
(800) 727-6677
www.gpworldwide.com

TITLE:

CLUSTER 7
SITES AND FEATURES

CARTOGRAPHER: B. JOYCE	APPROVED BY: T. DEREAMER	DATE: 01-22-03	FIGURE: 1-5
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1.5 Site Histories and Descriptions

Since the early 1930s, Northern Bush River has been used for general storage, chemical storage, and waste disposal. The Army primarily used the area as a storage facility for different types of materials used in research, testing, and production operations in the Edgewood Area from the 1930s to the present. Such materials included chemical agents (i.e., tear gas agents and raw materials for production use), general storage items, munitions, high explosives, and ammunition.

In the 1950s, the Army began using portions of Northern Bush River for open storage of construction-related materials. Other activities performed include the filling of selected locations adjacent to Lauderick Creek, and the breeding and testing of dogs for Army use. Portions of Northern Bush River were also used for the disposal of gas mask canisters, by means of burning, dumping, or burial (USAEHA, 1989). Currently, the APG Directorate of Installation Operations (DIO, formerly DPW) uses the northwestern and southwestern portions of Northern Bush River for storage of bulk materials (i.e., soil, sand, gravel, crushed stone, rock, and salvaged materials).

1.5.1 Boat Club Fill Sites (DSERTS # EABR07-A)

Located east of Cadwalader Road, the Boat Club Fill Sites (designated as Site 9 in the Generic Work Plan) lie within or adjacent to property used by the Gunpowder Neck Boat Club. The Boat Club Fill Sites consist of four separate locations, which have been labeled Sites 9A, 9B, 9C, and 9D for ease of reference (Figures 1-4 and 1-5). These fill material sites are the result of man-made, filling activities during the early 1940s (Sites 9A and 9D) and in 1988 (Sites 9B and 9C).

The purpose of filling and type of materials used during the early 1940s is unknown. The ground surface and field examinations at these locations indicate that Sites 9A and 9D were not dredge spoil disposal sites. A surveyor's notebook, with an entry date of May 27, 1942, only infers that these sites were fill areas (USAEHA, 1989). Located north of the Boat Club docks, Site 9A is approximately 75-by-600 feet in size. Site inspection indicates no evidence of filling. Located south of the Boat Club docks, Site 9D is approximately 100-by-300 feet in size. There is no surface evidence to indicate the type of material disposed of at the site.

The 1988 filling occurred at Sites 9B and 9C within a portion of the Boat Club. Located between the two northern docks, Site 9B was presumably filled to create dry land along the shore adjacent to the docks and near a picnic area. Approximately 300 feet in length, Site 9C was a former marsh filled in to create space for storing boats removed from the water during the winter months. The Army used topsoil stripped from the construction site for the Wheeled Vehicle Facility, located in Cluster 19 of the Other Edgewood Areas, to fill Sites 9B and 9C. The northern portion of the Wheeled Vehicle Facility construction site was later determined to be a fill site itself, having

received contaminated debris from the demolition of chemical plant facilities in the Canal Creek Study Area. Known contaminants at the Wheeled Vehicle Facility construction site include the degradation products sym-bis(2,4,6-trichlorophenyl)urea (TCPU) and chlorinated organic compounds from N,N'-dichloro-bis(2,4,6-trichlorophenyl)urea (CC2) manufacturing and clothing impregnating at chemical plant facilities. It is not known if the soil used as fill material at Sites 9B and 9C was stripped from the northern portion of the Wheeled Vehicle Facility site (USAEHA, 1989). Currently, Site 9B is grass-covered, while Site 9C is mainly covered with gravel.

1.5.2 Bio-Sensor Research Facility (DSERTS # EABR07-B)

As depicted in Figure 1-5, the former Bio-Sensor Research Facility (designated as Site 27 in the Generic Work Plan) was adjacent to the west side of Cadwalader Road. The facility supported a breeding and testing program to produce dogs superior in temperament, endurance, and intelligence for Army use. This operation began in the late 1960s, but has not been active since the 1970s. The dog population was several hundred. The facility consisted of buildings 840 (E2182), 842 (E2186), 844 (E2188), a kennel area, and a wastewater package treatment plant (E2189) (USAEHA, 1989).

The dog kennels were located immediately northwest of building 842 (E2186) on a 174-by-188 feet concrete slab with sloped surfaces, drainage channels, and water hydrants. The kennel area was spray-hosed daily to carry the kennel wastes through open concrete channels to the wastewater package treatment plant (USAEHA, 1989). The concrete slab is still present (Figure 1-5).

The wastewater package treatment plant was a Smith and Loveless Oxigest™ (Model 8) extended aeration, activated sludge plant, consisting of a flow control chamber, sludge storage tank, aeration equipment and tank, a clarifier, chlorination equipment, and a contact chamber. The plant, located west of building E2190 and north of the concrete slab, had an extended aeration residence time of 24 hours and a capacity of 40,000 gallons per day. The chlorination chamber, a semi-buried metal tank, lies in a grass field directly west of building E2190 and is covered with a metal lid. Visual inspection of the grass field identified land subsidence around the area. The chlorinated effluent discharged to Lauderick Creek, immediately west of the plant (USAEHA, 1989). The plant is no longer active and, as of April 1996, sewage effluent from building E2190 is routed to a lift station connected to a sewer line that extends south to the main sewer line from the Boat Club restrooms.

The wastewater generated by the former Bio-Sensor Research Facility was primarily from the dog kennels and consisted of feces, urine, hair, and small quantities of dog meal. The treatment plant also received sanitary wastewater from the buildings associated with the facility, and storm runoff from the kennel and building roofs. There is no information to indicate that the wastewaters from this facility contained hazardous constituents (USAEHA, 1989).

1.5.3 Gravel and Soil Storage (DSERTS # EABR35-A)

Located north of warehouse E2160 and 19th Street, Gravel and Soil Storage (designated as Site 22 in the Generic Work Plan) consists of three separate locations, which have been labeled Sites 22A, 22B, and 22C for ease of reference (Figure 1-4). The DIO, successor to DPW and the Directorate of Engineering and Housing, have used several locations for the storage of bulk materials. Aerial photographs taken in 1951 show three locations north of warehouse E2160 in use as open storage areas. The photographs showed rows of small objects, not piled bulk materials. The objects were not positively identified and could be either drums or sewer or drain pipe. Two of these locations correspond to Sites 22A and 22B; however, the additional location is inside the southwest corner of an old fence, north of the intersection of 19th Street and the gravel road, and southwest of building E2144. Site 22B was located within a former portion of the secured storage area in 1951 and the objects were in the center of the clearings. The 1958 aerial photographs show that Site 22A still contained stored materials. Site 22C was still heavily wooded at that time, with no visible evidence of former activities (USAEHA, 1989).

The DIO currently uses Site 22A to store bulk, construction-related aggregate (e.g., sand, gravel, crushed stone, rock). In 1995, one old, empty, rusted drum was outside the northwest corner beyond the aggregate piles. Site 22B has been used as a storage area for salvaged materials (e.g., scrap metal, plumbing materials, pipes, parts of appliances, plastics, and wooden pallets). Storage of soils at Site 22C began around 1989. The largest pile is topsoil stripped from the Wheeled Vehicle Facility construction site. Some of this topsoil was reported to be fill material, which could include contaminated debris from the demolition of chemical plant facilities (USAEHA, 1989). The Edgewood Area RFA reported no visible evidence of spills at Sites 22A, 22B, and 22C.

1.5.4 Buildings E2144, E2148, and E2150 (DSERTS # EABR35-B)

Buildings E2144, E2148, and E2150 are located in the northern portion of Northern Bush River (within a former fenced section) at the end of the gravel road leading to Lauderick Creek (Figure 1-4). Although the exact dates of their construction are unknown, the three buildings existed as early as 1933 for storage of high explosives. Potential usage of all three buildings was categorized from 1936, 1945, and 1966 facility listings to include chemical munitions storage, general chemical storage, and general storage (not necessarily chemical). Since 1989, the Army has reportedly used building E2148 to store transformers known or suspected to contain polychlorinated biphenyls (PCBs). The transformers were placed in metal pans for containment of possible leaks. Building E2150 is reported to have stored (circa 1966) radioactive source sets and could have been used for the storage of transformers. The Edgewood Area RFA reported no visible evidence of spills at these buildings (USAEHA, 1989).

None of the buildings have floor drains. A large metal storage rack with an attached smaller rack was at the "Y" in the road to buildings E2148 and E2150. The storage racks could have previously held storage tanks, but no tanks were present.

Building E2144 is a grass-covered semicylinder ("igloo") with one vent on top. The western side of the igloo consists of a corrugated metal tube entrance to wooden doors, facing the road. The remaining sides are sealed into the ground. Several irregularly shaped dirt mounds lie 50 feet to the northeast of the building. In 1995, site inspections identified old metal fence posts, metal cables, and a few old empty metal buckets east of the building.

Buildings E2148 and E2150 both consist of hollow (red-brick) tile-block on a thick reinforced concrete base, with a tarred roof and six vents on top. The entrance to E2148 faces east and E2150 faces west. Both buildings have wooden doors and wooden plank floors; one window is in the rear of each building. In 1995, a rusted metal trough made out of drum-halves and one old, empty, wooden munitions box were west of building E2148.

1.5.5 Warehouse Storage Areas (DSERTS # EABR36-A)

The Warehouse Storage Areas (designated as Site 19 in the Generic Work Plan) consist of 19 warehouses located throughout the central portion of the peninsula, inside and outside of the current secured storage area (Figure 1-4). Nine of the 19 warehouses (i.e., E2160, E2162, E2166, E2168, E2170, E2180, E2184, E2196, and E2198) lie within Northern Bush River. The remaining 10 warehouses lie within Southern Bush River. The Army built these warehouses in the early 1940s for general storage, and storage of high explosives and ammunition (USAEHA, 1989). Table 1-2 outlines available warehouse usage history.

Most of the warehouses are constructed of hollow (red-brick) tile-block on a reinforced concrete base, and their roofs appear to be made of corrugated Transite® asbestos. No floor drains were observed at any of the structures. The front of each warehouse faces a road. A continuous concrete loading dock, located in the rear of each building, faces an open alley where a rail spur once existed from the old rail line through the area. The Edgewood Area RFA reported that lethal chemical agents were probably not stored in these warehouses, but chemical materials could have been, such as "tear gas" agents and raw materials for production use. There is no information to indicate that leakage or spillage occurred in storage or handling operations. However, any release of contaminants resulting from historical operations at the warehouses would most likely be found in the soil around the doorways and loading docks.

Table 1-2. Northern Bush River Warehouse Usage History¹

Warehouse	Usage	Potential Contents
E2160 ²	General	DIO Supplies
E2162	HE, General	Thermite, IM, CN, CS, Smokes (Now Only Computer Supplies)
E2166	HE, General	Thermite, IM, CN, CS, Smokes
E2168 ²	General	Boats
E2170	General	Boats (Now Only Furniture)
E2180	General	Office Files and Supplies
E2184	General	Office Files and Supplies
E2196	General	DIO Supplies
E2198	HE, General	Thermite, IM, CN, CS, Smokes

¹Source: EAI Corporation, 1990²Built in 1942. All other warehouses built in 1941.

HE	High Explosives
DIO	Directorate of Installation Operations
Thermite	Aluminum powder and Ferric oxide
IM	Incendiary Munitions
CN	Chloroacetophenone (tear gas)
CS	Ortho-chlorobenzalmalononitrile (tear gas)

A water system or hydrants for fire protection serves all of the warehouses. Roads in the area drain to culverts and drainage gullies. All nine warehouses are large (approximately 65-by-200 feet), originally averaging 10 doors on each side. In addition, a sanitary sewer line from restrooms at the Boat Club runs westward immediately north of warehouses E2166, E2168, and E2170.

Aerial photographs taken in 1941 show a ground scar area bare of vegetation north of warehouse E2168 (USAEHA 1989). This fill area is now wooded. In 1995, earthen mounds, two old empty rusted drums, one old empty metal bucket, and some demolition debris were identified close to a nearby ditch, which drains west into a larger gully draining north.

1.5.6 Building 846 (E2194) Waste Disposal Site (DSERTS # EABR36-B)

The Building 846 (E2194) Waste Disposal Site (designated as Site 24 in the Generic Work Plan) lies adjacent to Bush River Road and south of 20th Street. Located outside the current secured

storage area, the site encompasses building E2194 (built in 1941 or 1942) and a paved parking lot to the northeast. A road salt storage dome (E2195) lies southeast of the building (Figure 1-4).

Aerial photographs taken in 1929 and 1940 indicate a ground scar area bare of vegetation at the site. In the 1980s, construction work to expand the parking lot uncovered the burned remains of gas masks and gas mask canisters at the northeastern edge of the site. The disposal area was very small, approximately 20 feet in length, but could have been larger because the soil observed in the aerial photographs toward the main portion of the site had not been significantly disturbed. Based on this evidence, the site was probably used as a burning site for wastes, which included gas mask canisters and portions of gas masks. The exact period of usage of the site is unknown, but estimated to be from sometime prior to 1929 through 1940. Gas mask canisters (filters) usually contain "Whetlerite," an activated carbon specially impregnated with metals, which act to catalyze the degradation of chemical agents. There is a possibility that the filters were contaminated with chemical agent because the gas mask materials were burned (USAEHA, 1989).

Currently, building E2194 is used for the maintenance of construction-related vehicles and storage of utility equipment. A 2,000-gallon capacity, underground fuel oil storage tank once existed at the northeast corner of building E2194, but was removed in April 1993. An aboveground fuel oil storage tank currently lies at the same surface location as the former underground storage tank (UST). An earthen berm lies along the back of the parking lot and parallels the woods. In 1995, two old empty drums, scrap metal, and a few railroad ties were near the earthen berm.

1.5.7 Drummed Soil Road Barricade Site (DSERTS # EABR36-A)

The Drummed Soil Road Barricade Site (designated as Site 26 in the Generic Work Plan) consists of two locations (labeled 26A and 26B) at entrance gates to the current secured storage area in the central portion of the Bush River Study Area. As shown in Figure 1-4, only Site 26A lies within Northern Bush River. During 1986 and 1987, the Edgewood Area RFA reported that the Army used 101 drums filled with soil as road barricades immediately inside the secured storage area on Bush River Road between 21st and 22nd Streets, as well as at Site 26B. The soil in the drums came from other locations in the Edgewood Area. The USAEHA and USEPA National Enforcement Investigation Center sampled a number of the drums during August 1987. Analysis of the drummed soil indicated concentrations of several organic contaminants in the drummed soil, including PCBs (e.g., Aroclor 1254 and Aroclor 1248), organic constituents (e.g., acetone, tetrahydrofuran, 2-butanone, and bis(2-ethylhexyl)phthalate), and polycyclic aromatic hydrocarbons (PAHs). Later, the drums were transported to F-Field near the Chemical Transfer Facility for proper disposal off-post (USAEHA, 1989). There is no visible evidence that contaminated soil spilled or leaked at Site 26A.

1.5.8 Boat Club Ship Store (Building E2169) (DSERTS # EABR36-A)

Building E2169 lies southeast of the intersection of 20th Street and Cadwalader Road, outside the current secured storage area (Figure 1-4). Neither the Edgewood Area RFA nor the EAI Building Assessment provides any information on the date of construction or past use for building E2169. Building E2169 is approximately 25-by-25 feet in size and could have served as an office for the warehouses. Currently, the building serves as a store and office for the Boat Club. Field examinations in 1995 identified a very small amount of stained soil immediately below an aboveground fuel oil storage tank located on the east side of the building. Utility maps indicate a vitrified clay pipe connected to building E2169 runs eastward to a septic tank past warehouse E2170. The septic tank is located at the southeast end of 20th Street near a steep drainage gully.

1.5.9 DPW Southwest Storage Areas (DSERTS # EABR36-A)

The DPW Southwest Storage Areas lie within open areas and woods southwest of buildings E2160 and E2162, and south of Bush River Road (Figure 1-4). Aerial photographs taken in 1951 indicate the existence of open storage areas for construction-related materials in this portion of Northern Bush River (USAEHA, 1989).

The Edgewood Area RFA did not report any visible evidence of contamination at these storage areas. The sanitary sewer line continues southwest through a clearing in the area. DIO has stored sand and stone piles, land clearing debris (e.g., trees and brush), utility poles, old railroad ties, and concrete culverts at some of the open areas. In 1995, the remains of six old, rusted drums were found partially buried just inside the woods beyond the southwest corner of building E2194. Irregular shaped mounds, metal pipes, nuisance trash, and scrap metal were near a drainage gully. Site inspections also found two, six-inch diameter metal pipes, sealed with unusual caps and protruding aboveground, in the woods. These pipes are believed to be part of an abandoned water line.

1.6 Overview of Previous Investigations

The first relevant study conducted in Northern Bush River was the Edgewood Area RFA, completed in 1989 under a RCRA Corrective Actions Permit. The RFA refined preliminary assessment and site investigation work, documented historical activities at the Edgewood Area related to solid waste management, and identified and described 319 solid waste management units (SWMUs). The FFA mandated further investigations under CERCLA; however, the Edgewood Area RFA recommended the following actions concerning Northern Bush River:

Boat Club Fill Sites (Sites 9A, 9B, 9C, 9D)

- Perform sampling and analysis to evaluate potential impacts on human health and the environment. The sampling should include surface water samples collected adjacent to the fill sites and surface soil samples from within the fill. If hazardous constituents are detected above background levels, a risk assessment should be performed to assess threats to human health, with the primary consideration being ingestion of soil by children.

Bio-Sensor Research Facility (Site 27)

- No future sampling and analysis or corrective action work to address the former Bio-Sensor Research Facility are necessary.

Gravel and Soil Storage (Sites 22A, 22B, 22C)

- Prevent use of the pile of topsoil stored near building 812 (E2144), which was removed from the Wheeled Vehicle Facility construction site, until sampling and analysis shows the area to be free of hazardous constituents.

Warehouse Storage Areas (Site 19)

- The Edgewood Area RFA already addresses the performance of investigation work at SWMUs in which historical chemical release is known or suspected to have occurred. These studies adequately address contaminant migration from the non-SWMU storage sites.
- If construction work or other activities do not disturb the storage sites, no further study work is necessary for the non-SWMU storage sites. Perform appropriate protective measures and/or sampling and analysis if use of the storage areas changes, or if there are activities that could result in exposure to contaminants in the soil.

Building 846 (E2194) Waste Disposal Site (Site 24)

- Survey the area to determine the location with respect to existing roads and buildings.
- Sample and analyze the soil to determine if there are hazardous constituents present in the surface soil within Site 24.
- Perform soil vapor sampling and analysis at a minimum of 10 locations within, and immediately downgradient of, Site 24. If hazardous VOC contaminants are found to be present, consider performing groundwater quality study work.

Drummed Soil Road Barricade Site (Site 26A)

- RCRA Facility Investigation work at the Drummed Soil Road Barricade Site is unnecessary because there was no release of hazardous constituents.

Buildings E2144, E2148, and E2150; Boat Club Ship Store (Building E2169); and DPW Southwest Storage Areas

- No recommendations for further action were made for these sites.

1.6.1 Boat Club Fill Sites

Between September 11 and 13, 1989, USAEHA performed soil sampling at the Boat Club Fill Sites (i.e., Sites 9B, 9C, 9D) to assess potential environmental contamination at the sites. The investigation involved surface and subsurface soil sampling along the shoreline between the two northern docks at Site 9B and the northern portions of Sites 9C and 9D. The investigation was conducted because of concern that contaminated soil from the Wheeled Vehicle Facility construction site could have been used as fill in Sites 9B and 9C (Speetzen, 1990). A previous USAEHA study identified potential contamination in a mound of soil near the Wheeled Vehicle Facility construction site in 1988 (USAEHA, 1989).

USAEHA performed a total of 10 subsurface soil borings and collected six surface soil samples within the three fill areas. Each boring was drilled to the bottom of the fill material and samples were collected at designated intervals from each boring and submitted for organic and inorganic analyses. A background sample was also collected from a boring near the gate at the entrance to the Gunpowder Neck Boat Club. Four subsurface borings were conducted within Site 9B along the dock shoreline. Boring depths at Site 9B ranged from the surface to 66 inches below grade. One to three samples were collected at designated intervals from within each boring. In the northern portion of Site 9C, five subsurface borings were conducted along the dock shoreline. Boring depths within Site 9C ranged from the surface to 22 inches below grade. A composite soil sample from the entire depth of each boring was collected. Within Site 9D, six surface soil samples were collected along the tree line bordering the parking lot area. Samples were collected from the surface down to a depth of 12 inches. Field personnel collected soil samples from the borings by using the weight of the drill rig to push a split spoon sampler into the ground. The borings indicated that the fill areas were underlain by construction debris, broken concrete, and some asphalt. At three sample points, the construction debris precluded sampling to the bottom of the fill material. The USAEHA laboratory performed the inorganic analyses and Lancaster Laboratories, Inc. performed the organic analyses (Speetzen, 1990).

Contamination was found in the fill material in low concentrations. No VOCs were identified during the study, except for a dimethylbenzene isomer detected at 6.8 micrograms per Kilogram ($\mu\text{g/Kg}$) or parts per billion (ppb) in one Site 9B soil sample. The highest concentrations and

numbers of semivolatile organic compounds (SVOCs) were detected in a surface sample from one Site 9B boring. Soil sample results from this boring revealed the presence of the PAHs phenanthrene at 1,245 µg/Kg and pyrene at 1,390 µg/Kg. These chemicals are consistent with compounds detected from the analysis of residue from burning charcoal. Since this boring is near the boat club's barbecue grills, ashes likely explain the presence of these compounds. Lower concentrations of the PAHs chrysene, benzo(b)fluoranthene, fluoranthene, and pyrene were also detected in two borings within Site 9C. The highest concentration of cadmium was detected in one sample from a Site 9C boring at 7 milligrams per Kilogram (mg/Kg) or parts per million (ppm). Mercury was detected at low concentrations (i.e., 0.13 mg/Kg) in one boring located within Site 9B. Low levels of dichloro-diphenyl-trichloroethane (4,4'-DDT) and its degradation products (i.e., dichloro-diphenyl-dichloroethene [4,4'-DDE] and dichloro-diphenyl-dichloroethane [4,4'-DDD]) were detected in all 10 borings and six surface soil sample locations. The highest concentrations were 4,4'-DDT at 1.92 µg/Kg, 4,4'-DDE at 1.68 µg/Kg, and 4,4'-DDD at 0.38 µg/Kg. No PCBs were detected. As a result of this investigation, USAEHA recommended coordination with State of Maryland regulatory agencies to determine if further action at the Boat Club Fill Sites was required (Speetzen, 1990). As a result, additional work was performed and presented in this RI.

1.6.2 Gravel and Soil Storage Site 22C

Soil samples collected in May 1993 from the soil pile at Site 22C were tested using the Toxicity Characteristic Leaching Procedure (TCLP). These samples were also analyzed for PCBs, pesticides/herbicides, total petroleum hydrocarbons (TPH), benzene/toluene/ethylbenzene/xylene (BTEX), and 2,4,6-trichloroaniline (General Physics Environmental Services, 1993). Detected analytes and their maximum concentrations in the soil pile were: di-n-butylphthalate at 40.0 µg/kg, fluoranthene at 41.6 µg/Kg, pyrene at 45.8 µg/Kg, barium at 397 micrograms per Liter (µg/L), TPH at 56.6 mg/Kg, 4,4'-DDD at 3.26 µg/Kg, 4,4'-DDE at 9.29 µg/Kg, and 4,4'-DDT at 8.84 µg/Kg. In addition, the soil pile at 22C was re-sampled for TPH in April 1994. These results were below quantification limits (General Physics Environmental Services, 1994).

1.7 Associated Work Plans and Remedial Investigation Documents

The Northern Bush River RI incorporates the guidance of multiple work plans based on requirements in the FFA. USACE developed the approved Generic Work Plan, which presents the general RI/FS plan and generic field sampling plan applicable to sites identified for study in the Edgewood Area (specifically in the Bush River, Lauderick Creek, Westwood, and Other Edgewood Area Study Areas). The Detailed RI Work Plans, containing plans for sampling and analysis, health and safety, and related tasks specific to individual clusters of sites, are separate documents located in Appendix I of the Generic Work Plan. Appendix J of the Generic Work Plan provides Standard Operating Procedures (SOPs) detailing sampling and technical procedures employed during RI

work (USACE, Baltimore District, 1992). DSHE and its contractors performed all work in accordance with the FFA between the USEPA Region III, APG, and the U.S. Department of the Army.

Before initiating field activities, contractors prepared scoping documents according to USEPA guidance (USEPA, 1988a and b). The documents were reviewed by APG IRP, USEPA Region III, and MDE and served as the basis for conducting the Northern Bush River RI activities discussed in this report. These documents include the following:

- *Detailed Work Plan for Regional Geotechnical Investigation, Edgewood Area, Aberdeen Proving Ground* (USACE, Baltimore District, 1991). This plan details specific work for characterizing hydrogeologic conditions at the Bush River, Westwood, Lauderick Creek, and Other Edgewood Area Study Areas.
- *Draft Final Work Plan, Boat Club Area Fill Sites, Cluster 7, Bush River Area* (USACE, Baltimore District, 1995a). This plan presents site-specific details of work accomplished for the Cluster 7 portion of the Northern Bush River RI (i.e., Boat Club Fill Sites and Bio-Sensor Research Facility). Outlined work includes groundwater monitoring well installations and groundwater, surface water, sediment, and surface soil sampling.
- *Work Plan Addendum for the Remedial Investigation at Cluster 7, Bush River Study Area, Edgewood Area, Aberdeen Proving Ground, Maryland* (Earth Tech, Inc. and GP, 1996c). This addendum outlines supplemental work accomplished at Cluster 7, which provided additional information on Boat Club Fill Sites 9A and 9D, the southern portion of Site 9C, and the wastewater package treatment plant associated with the Bio-Sensor Research Facility Site. Supplemental work includes surface and subsurface soil, and sludge sampling.
- *Detailed RI Work Plan for Cluster 35 of the Bush River Study Area, Edgewood Area, Aberdeen Proving Ground* (GP, 1994b). This plan presents site-specific details of work accomplished for the Cluster 35 portion of the Northern Bush River RI (i.e., Gravel and Soil Storage and Buildings E2144, E2148, and E2150). Outlined work includes soil gas surveys, groundwater monitoring well installations, and groundwater, surface water, sediment, and surface soil sampling.
- *Detailed RI Work Plan for Cluster 36 of the Bush River Study Area, Edgewood Area, Aberdeen Proving Ground* (GP, 1994c). This plan presents site-specific details of work accomplished for the Cluster 36 portion of the Northern Bush River RI (i.e., Warehouse Storage Areas, Building 846 (E2194) Waste Disposal Site, Drummed Soil Road Barricade Site, Boat Club Ship Store (Building E2169), and DPW Southwest Storage Areas).

Outlined work includes soil gas surveys, groundwater monitoring well installations, and groundwater, surface water, sediment, surface soil, and sludge sampling.

Additionally, the following documents outline the analytical and quality assurance/quality control (QA/QC) procedures implemented, and specific health and safety protocols required during Northern Bush River field investigations:

- *Site-Specific Health and Safety Plan, Monitoring Well Installation for Cluster 7, Edgewood Area, Aberdeen Proving Ground* (USACE, Baltimore District, 1995b).
- *Bush River Study Area Health and Safety Plan for RI/FS Activities, Edgewood Area, Aberdeen Proving Ground* (GP, 1994a).
- *Bush River and Lauderick Creek Study Areas Quality Assurance Project Plan, Edgewood Area, Aberdeen Proving Ground* (GP, 1995a).

As part of the data evaluation in this RI Report, groundwater, surface water, sediment, soil, and sludge analytical results are compared to the range of reference values from the U.S. Army Environmental Center (AEC) reference sampling program completed by ICF Kaiser Engineers, Inc. The results of the reference sampling program are reported in the *APG Reference Sampling and Analysis Program Groundwater Reference Data Report* (ICF Kaiser Engineers, Inc., 1995a) and *APG Reference Sampling and Analysis Program Soil, Sediment, and Surface Water Reference Data Report* (ICF Kaiser Engineers, Inc., 1995b). Reference data were collected from outside the Installation at sampling points unrelated to the designated Northern Bush River sampling sites. The reference sampling was conducted to evaluate the abundance and nature of certain analytes in groundwater, surface water, sediment, and surface soil sample points dispersed throughout the surrounding areas of Harford, Baltimore, Kent, and Cecil counties.

The Technical Plan for Risk and Biological Impact Assessment at U.S. Army Aberdeen Proving Ground, Maryland Volume I (ICF Kaiser Engineers, Inc., 1993) describes the general approach for evaluating potential impacts at various trophic levels within both aquatic and terrestrial communities at APG. Volume II, Appendix D, of the Technical Plan provides the work plan for conducting human health and ecological risk assessments at the Bush River Study Area, which outlines the plan for addressing both human health and ecological effects of chemical contamination (ICF Kaiser Engineers, Inc., 1995c).

The Baseline Risk Assessment for the Northern Bush River Area, Aberdeen Proving Ground, Maryland (ICF Kaiser Engineers, Inc., 1997) provides an evaluation of potential human health risks associated with identified chemicals of potential concern (COPCs), based on a separate analysis of environmental monitoring data collected as part of the RI. The screening-level *Ecological Risk*

Assessment for the Northern Bush River Area, Aberdeen Proving Ground, Maryland (IT Corporation, 2000) provides a screening-level evaluation of potential ecological impacts associated with identified COPCs, based on a separate analysis of environmental monitoring data collected as part of the RI.

2.0 STUDY AREA INVESTIGATION

This section summarizes the Northern Bush River RI program and provides an overview of certain common program elements (e.g., environmental sample collection, chemical analyses, geological investigations, etc.) and other components (e.g., soil gas surveys, thermal imaging study, data management, etc.), including the rationale and approach used for the RI program.

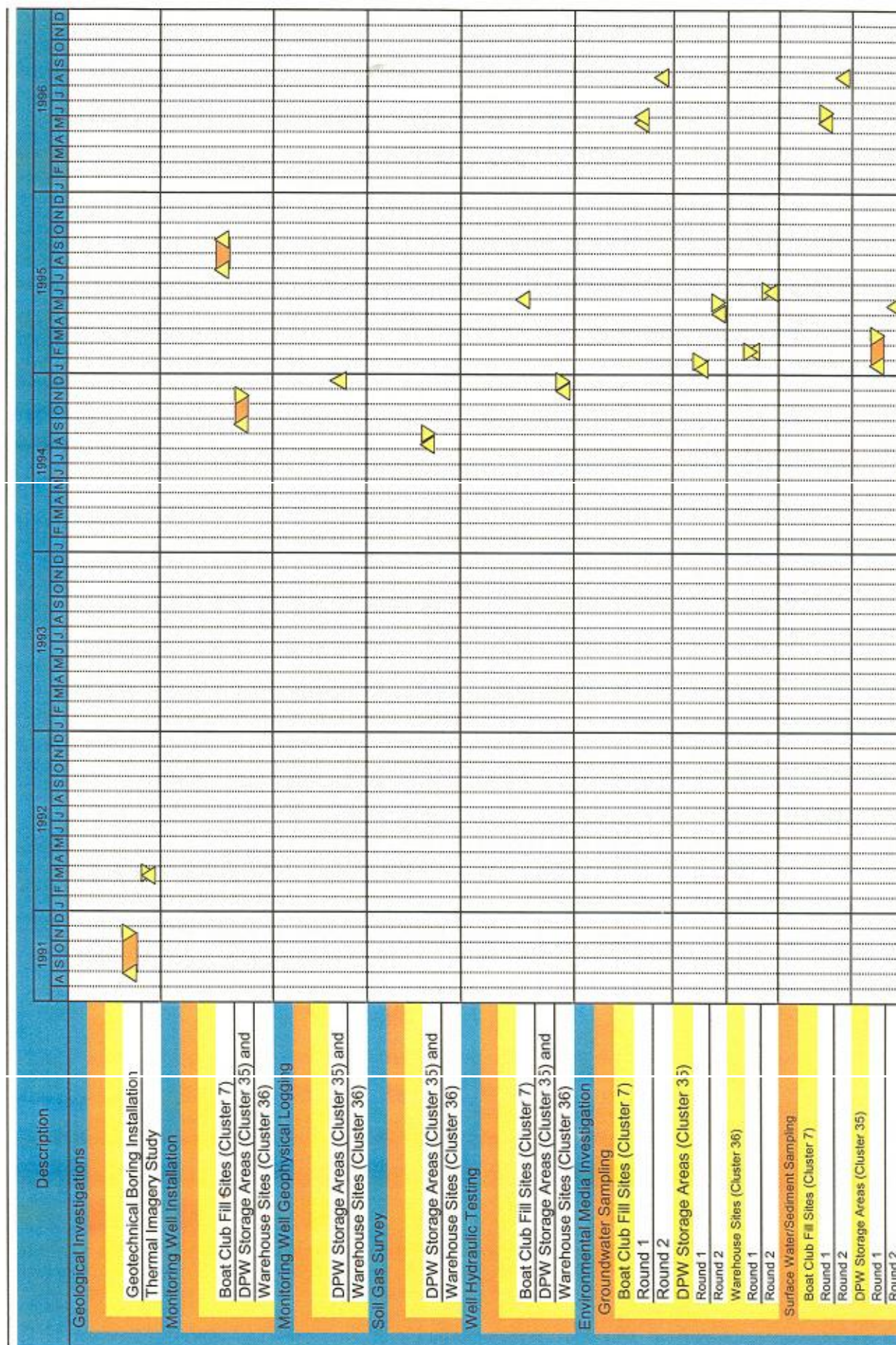
Available site-specific historical, geographic, geologic, and hydrogeologic information were evaluated to develop field characterization techniques and sampling network designs for this project. In addition, field characterization techniques and sampling designs were selected after evaluation of potential contaminants, sources, and contaminant migration pathways (e.g., location of sites, aquifers, and surface water runoff drainage patterns). Sound engineering and hydrogeologic principles served as the basis for all sampling network design and field characterization development decisions. Field characterization techniques, sampling locations, and network designs were chosen in consultation with the following: DSHE, Environmental Conservation and Restoration Division; USEPA Region III; MDE; APG's risk assessment contractor, ICF Kaiser Engineers, Inc. (now IT Corporation); USACE Baltimore District and Waterways Experiment Station; Earth Tech, Inc.; and GP.

Figure 2-1 summarizes the sequence of RI activities conducted at Northern Bush River. Table 2-1 summarizes the major elements of the RI sampling program, presenting information on the number of environmental samples collected, parameters analyzed, and other field program elements, such as soil gas surveys.

2.1 Review of Historical Documents and Aerial Photographs

The review of historic documents and aerial photographs pertaining to Northern Bush River identified potential source areas and aided in the development of the RI Work Plans for sampling various environmental media. The records review used available documents to reconstruct a general history of site operations at Northern Bush River, and provide information on the site-specific geographical and physical settings.

Before initiating RI field work, DSHE and its contractors reviewed the interpretation of historic aerial photographs dated 1929, 1940, 1941, 1951, 1958, and 1970 presented in the Edgewood Area RFA (USAEHA, 1989). The aerial photographs assisted in further evaluating potential source areas, reconstructing activities over time, identifying land use changes, and aiding in the selection of environmental media sampling locations. Field examinations validated interpretations regarding the presence of roads, structures, cleared areas, barren soil areas, suspected burn and waste disposal sites, drainage features, and pits or depressions noted on the aerial photographs and maps.



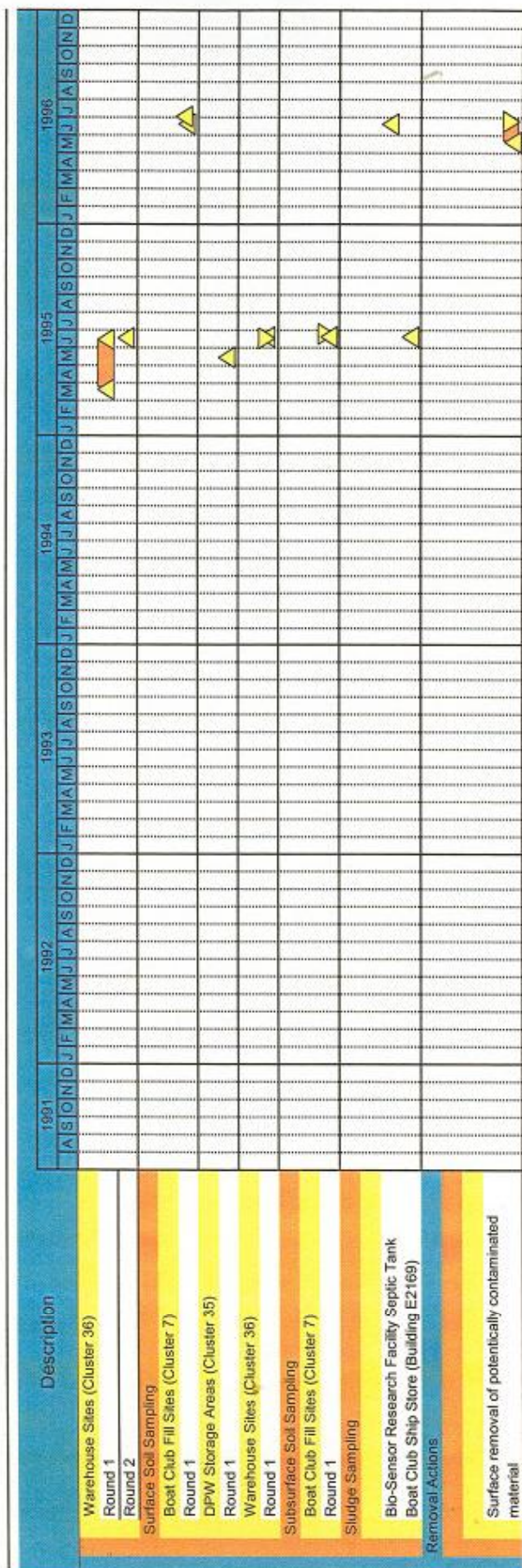


Figure 2-1. Northern Bush River Remedial Investigation Program Activities

Table 2-1. Summary of RI Sampling Program at Northern Bush River (Continued)

Medium/Type of Investigation	First Round		Second Round		Additional Sampling/Investigations	
	Number of Samples	Parameters	Number of Samples	Parameters	Number of Samples	Parameters
Gravel and Sand Storage (Sites 22A, 22B, 22C) DSERTS Number EABR35-A						
Soil Gas Survey					60	V,S
Surface Soil	7	Agent Screening ^a	7	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Surface Water	2	V,S,E,A,P/p, R(a,b),I,W	2	V,S,E,A,P/p, R(a,b),I,W		
Sediment	2	Agent Screening ^a	2	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Groundwater	7	V,S,E,A,P/p, R(a,b),I,W	7	V,S,E,A,P/p, R(a,b),I,W		
Buildings E2144, E2148, and E2150 (Unnumbered) DSERTS Number EABR-35B						
Soil Gas Survey			28	V,S		
Surface Soil	7	Agent Screening ^a	7	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Surface Water	3	V,S,E,A,P/p, R(a,b),I,W	3	V,S,E,A,P/p, R(a,b),I,W		
Sediment	4 ^b	Agent Screening ^a	4 ^b	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Groundwater	2	V,S,E,A,P/p, R(a,b),I,W	2	V,S,E,A,P/p, R(a,b),I,W		

Table 2-1. Summary of RI Sampling Program at Northern Bush River (Continued)

Medium/Type of Investigation	First Round		Second Round		Additional Sampling /Investigations	
	Number of Samples	Parameters	Number of Samples	Parameters	Number of Samples	Parameters
Warehouse Storage Areas (Site 19) DSERTS Number EABR36-A						
Soil Gas Survey					56	V,S
Surface Soil	1	Agent Screening ^a	1	V,S,E,A,P/p, R(a,b), I, TOC, SA		
Surface Water	1	V,S,E,A,P/p, R(a,b), I, W	1	V,S,E,A,P/p, R(a,b), I, W		
Sediment	1	Agent Screening ^a	1	V,S,E,A,P/p, R(a,b), I, TOC, SA		
Groundwater	4	V,S,E,A,P/p R(a,b), I, W	4	V,S,E,A,P/p R(a,b), I, W		
Building 846 (E2194) Waste Disposal Site (Site 24) DSERTS Number EABR36-B						
Soil Gas Survey					35	V,S
Surface Soil	2	Agent Screening ^a	2	V,S,E,A,P/p, R(a,b), I, TOC, SA		
Groundwater	3	V,S,E,A,P/p, R(a,b), I, W	3	V,S,E,A,P/p, R(a,b), I, W		
Drummed Soil Road Barricade Site (Site 26A) DSERTS Number EABR36-A						
Soil Gas Survey					15	V,S
Surface Soil	4	Agent Screening ^a	4	V,S,E,A,P/p, R(a,b), I, TOC, SA		
Surface Water	1	V,S,E,A,P/p, R(a,b), I, W	1	V,S,E,A,P/p, R(a,b), I, W		
Sediment	1	Agent Screening ^a	1	V,S,E,A,P/p, R(a,b), I, TOC, SA		
Groundwater	1	V,S,E,A,P/p, R(a,b), I, W	1	V,S,E,A,P/p, R(a,b), I, W		

Table 2-1. Summary of RI Sampling Program at Northern Bush River (Continued)

Medium/Type of Investigation	First Round		Second Round		Additional Sampling/Investigations	
	Number of Samples	Parameters	Number of Samples	Parameters	Number of Samples	Parameters
Boat Club Ship Store (E2169) (Unnumbered) DSERTS Number EABR36-A						
Soil Gas Survey					4	S,V
Groundwater	1	V,S,E,A,P/p, R(a,b),I,W	1	V,S,E,A,P/p, R(a,b),I,W		
Sludge			1	V,S,E,A,P/p, R(a,b),I,TOC,SA		
DPW Southwest Storage Areas (Unnumbered) DSERTS Number EABR36-A						
Surface Soil	2	Agent Screening ^a	2	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Surface Water	2	V,S,E,A,P/p, R(a,b),I,W	2	V,S,E,A,P/p, R(a,b),I,W		
Sediment	2	Agent Screening ^a	2	V,S,E,A,P/p, R(a,b),I,TOC,SA		
Groundwater	2	V,S,E,A,P/p, R(a,b),I,W	2	V,S,E,A,P/p, R(a,b),I,W		

Legend:

V=Volatile Organic Compounds
S=Semi-volatile Organic Compounds
P/p=Pesticides/Polychlorinated Biphenyls
E=Explosive-related Compounds
A=Chemical Agent Degradation Products

R=Radiological Parameters
a=Gross Alpha
b=Gross Beta
g=Gamma Spectral Analysis
I=Inorganics

W=Water Quality Parameters
TOC=Total Organic Carbon
SA=Sieve Analysis

Note: Total number of samples in Table 2-1 does not correspond with total number of media sampling points because some media sampling points are potentially downgradient of more than one site. See Tables 2-2 and 2-5 for relationship of media sampling points to sites. Total media sampling points consisted of 19 surficial aquifer groundwater monitoring wells, 13 surface water and 14 sediment points, 30 surface soil, 8 subsurface soil, and 2 sludge (water) samples.

- (a) UXO Clearance and chemical agent material screening conducted during all intrusive activities.
(b) Only a sediment sample (C35-SD-05) was collected within a munitions disposal area along the Lauderick Creek shoreline.

2.2 Surface Features Investigation

DSHE and its contractors performed field reconnaissance to support development of the Northern Bush River RI Work Plans and verify interpretations of aerial photographs. Field surveys involved visually observing man-made and natural surface features at Northern Bush River including conditions at suspect features (e.g., drums, mounds, underground storage tanks [USTs], physically disturbed or stained soil areas, and barren vegetation). Visual examinations also verified site geology, physical features, and land use. Based on the field reconnaissance data, DSHE and its contractors were able to finalize the sampling locations and assess the need for removal actions.

2.3 Geophysical Investigations

The following paragraphs present a brief discussion of the monitoring well geophysical logging and unexploded ordnance (UXO) avoidance and clearance for intrusive activities conducted at Northern Bush River. The results of the geophysical logging were correlated with all existing geological information concerning Northern Bush River.

2.3.1 Monitoring Well Geophysical Logging

To complement the geologic database for Northern Bush River, DSHE contractors conducted borehole geophysical surveys in 15 groundwater monitoring wells in December 1994. The geophysical survey method involved natural gamma surveying (logging) as a function of depth. Natural gamma logging involves measuring the natural rate of emissions of gamma radiation by geologic materials surrounding the borehole. These methods assisted in qualitative stratigraphic characterization and correlation between boreholes.

Enviroscan, Inc., under subcontract to GP, performed natural gamma logging on 15 of the 19 wells during December 1994 (GP, 1995e). These wells included: WBR-70, -74 through -84, -86, -87, and -88. The contractor logged all wells to the maximum accessible depths in the wells, ranging from a minimum of 13 feet to a maximum of 45 feet.

2.3.2 UXO Clearance for Intrusive Activities

Because surface or subsurface UXO or other items might be found in Northern Bush River, UXO surveys of work areas were required. UXO survey teams from an APG-approved explosive ordnance disposal contractor implemented an ordnance avoidance program during the collection of all intrusive environmental samples. Before installing wells, UXO survey teams conducted visual inspections; and magnetically swept, flagged, and cleared the work areas of all metallic objects.

During all intrusive work, the contractor monitored for chemical warfare agents using an individual chemical agent detector, which is a warning device worn at the waist level that sounds an alarm upon detection of nerve, blood, choking, and blister agent vapors. The U.S. Army Technical Escort Unit removed any recovered UXO encountered during the clearance of drill rig access paths and borehole locations, and at a munitions disposal area along the Laudrick Creek Shoreline.

2.4 Geological Investigations

Geological investigations at Northern Bush River refined existing knowledge regarding the geology and hydrogeology of the area. APG IRP and its contractors evaluated the data to: understand the interaction between streams and groundwater; locate groundwater discharge into wetlands, Laudrick Creek, and Kings Creek; and define the deep and near-surface stratigraphy of Northern Bush River. The following subsections provide information concerning these studies. Section 3 discusses the interpretation of the geological investigations.

2.4.1 Geotechnical Borings

USACE drilled five geotechnical borings designated BR-1 through BR-5 (Figure 1-3) in the Bush River Study Area between August and November 1991. These exploratory borings assisted in characterizing the stratigraphy and arrangement of aquifers, and determining potential contaminant migration and extent within the study area (USACE, Baltimore District, 1991). Boring BR-1 is at the eastern edge of Cluster 3 along Old Bush River Road and approximately 175-feet deep. Boring BR-2 is east of boring BR-1 and approximately 185-feet deep. Borings BR-3 and BR-4 are both just north of Bush River Road. Boring BR-3 is southeast of boring BR-2 and approximately 190-feet deep; and boring BR-4 is southeast of BR-3 and approximately 215-feet deep. Boring BR-5 is furthest east near the shoreline of Bush River and approximately 220-feet deep.

The mud rotary drilling method was used to complete the borings. Individual aquifers were cased-off to prevent migration of possible contamination from one aquifer to another. A five-foot long, internally mounted core sampler was used to obtain stratigraphic samples. All samples were screened for the presence of organic vapors in accordance with SOP 019 of Appendix J to the Generic Work Plan. In addition, each borehole was logged for spontaneous potential, natural gamma, and resistivity. Each boring was permanently sealed with a bentonite/grout mixture at the completion of work.

Data analysis from this effort helped define stratigraphy, aquifer characteristics, depth of water table, and hydraulic gradients. This information aided in the location and design of groundwater monitoring wells. One stratigraphic cross section in Section 3 incorporates the hydrogeologic information and borehole logs obtained from geotechnical borings BR-1 through BR-5.

2.5.1 Monitoring Well Installation

A total of 19 monitoring wells were installed during the RI to define the hydrogeology and groundwater quality of the surficial aquifer at Northern Bush River. Between September 12, 1994 and November 15, 1994, GP installed 15 wells in the northern, central, and southern portions of Northern Bush River (i.e., Cluster 35 DPW Storage Areas and Cluster 36 Warehouse Sites). USACE installed the remaining four monitoring wells in the northeastern portion of Northern Bush River (i.e., Cluster 7 Boat Club Fill Sites) between July 26, 1995 and September 6, 1995. In addition, five drilled borings (i.e. BBR-12, -66, -69, -73, and -85) were properly abandoned. Figure 2-2 depicts the locations of the groundwater monitoring wells.

DSHE and its contractors chose the well locations to allow for coverage of Northern Bush River; investigate specific areas identified by the review of historical documents, aerial photography, and surface feature investigations; and provide sufficient data to perform a risk assessment. Secondary objectives of the boring program included characterizing the stratigraphy of the surface aquifer and determining the possible presence of non-aqueous phase liquids (NAPLs) contamination localized either above subsurface silt/clay layers (i.e., denser than water NAPL or DNAPL) or at the surface of the groundwater (i.e., less dense than water NAPL or LNAPL). Table 2-2 identifies the relationship each surficial aquifer well has to potential source areas in Northern Bush River.

All exploratory borings were advanced using continuous flight, hollow stem augers. All wells were constructed with 4-inch-diameter polyvinyl chloride risers and 0.01-inch slotted screens, and grouted in place at the surface with a cement/bentonite slurry. Field observations and predetermined criteria provided by the RI Work Plans and SOPs 010 and 019 of Appendix J to the Generic Work Plan established the basis for installation of the monitoring wells. A Well Installation Report (GP, 1995e) and USACE well logs describe the well installation process at Northern Bush River, including site clearance and preparation, drilling, stratigraphic sampling, air/vapor monitoring, well construction and development, decontamination, site restoration, and surveying.

2.5.2 Well Hydraulic Testing

Geologists conducted well hydraulic testing on the 19 surficial aquifer groundwater monitoring wells in Northern Bush River to obtain hydraulic conductivity (K) and transmissivity (T) data. GP performed the testing on 15 of the wells (i.e., WBR-70, -74 through -84, -86, -87, and -88) from December 14 through December 22, 1994 (GP, 1995b) and the remaining four wells (WBR-11, -12, -13, and -15) on May 30 and May 31, 1996 (Earth Tech, Inc and GP, 1996b). Borehole logs from each well were used to designate wells as either confined or unconfined for purposes of performing the test. Wells screened in semi-confined conditions were designated as confined. A

Table 2-2. Monitoring Well Locations Correlated to Northern Bush River Sites

Site Name	Well Designation ¹	Relationship
Boat Club Fill Sites (Sites 9A, 9B, 9C, 9D)	WBR-11	Adjacent to fill Site 9A.
	WBR-13	Adjacent to fill Site 9D.
Bio-Sensor Research Facility (Site 27)	WBR-12	Adjacent to former wastewater package treatment plant septic system.
	WBR-11, WBR-15	Down gradient of site.
Gravel and Soil Storage (Sites 22A, 22B, 22C)	WBR-81	Up gradient of storage sites.
	WBR-82, WBR-83	Down gradient of Site 22A.
	WBR-82	Cross gradient of Site 22B.
	WBR-84, WBR-86	Down gradient of Site 22C.
	WBR-76, WBR-80	Down gradient of storage sites.
Buildings E2144, E2148, and E2150 (Unnumbered)	WBR-87	Within entrance to buildings E2148 and E2150, and down gradient of storage racks.
	WBR-88	Down gradient from building E2144.
Warehouse Storage Areas (Site 19)	WBR-13	Down gradient of warehouses E2200 and E2204.
	WBR-75	Down gradient from fill area behind building E2168.
	WBR-74	Down gradient from warehouses E2168 and E2198.
	WBR-79	Down gradient from warehouses E2160 and E2162.
Building 846 (E2194) Waste Disposal Site (Site 24)	WBR-77, WBR-78	Cross gradient of site.
	WBR-79	Down gradient of site.
Drummed Soil Road Barricade Site 26A (Site 26A)	WBR-70	Down gradient of site.
Boat Club Ship Store (Building E2169) (Unnumbered)	WBR-74	Down gradient of site.

¹Wells are potentially downgradient or upgradient from other sites.
WBR = Bush River Groundwater Monitoring Well

rising head slug test was used for wells designated as existing in unconfined portions of the aquifer; a falling head slug test was used for wells designated as existing in confined portions of the aquifer. The geologists performed the tests using a sand-filled polyvinyl chloride slug or a stainless steel 3-inch bailer attached to new polyethylene cord. An In-situ, Inc. Troll™ data logger, controlled by a portable personal computer, recorded time-versus-displacement data in the field. Field geologists performed all well hydraulic testing in accordance with SOP 033 of Appendix J to the Generic Work Plan. Section 3 presents well hydraulic data for Northern Bush River.

2.5.3 Water Level Measurements

DSHE contractors carried out three rounds of synoptic water level measurements at the Northern Bush River monitoring wells on March 6, June 24, and October 11, 1996 in support of the APG IRP. In addition, the sampling teams collected water level measurements prior to each groundwater sampling event to determine differences in shallow groundwater flow over wet and dry periods. The contractor collected water level measurements using an electronic water level indicator graduated in 0.01-foot increments in accordance with SOP 010 of Appendix J to the Generic Work Plan. Section 3 lists all data collected during groundwater level measurements in March, June, and October of 1996. Before the initial round of sampling at each monitoring well, personnel checked each well for the presence of LNAPLs and DNAPLs using an interface probe capable of determining phases as thin as 1/8-inch thick.

2.5.4 Groundwater Sampling and Analysis

As part of the Northern Bush River RI program, GP collected two rounds of groundwater samples at 19 monitoring wells for chemical analysis at designated dates between January 1995 and August 1996 (Figure 2-2). Figure 2-2 showed the groundwater monitoring well locations. Table 2-3 presents the dates for each groundwater sampling event and the sample locations associated with each event. The primary purpose for collecting these samples was to evaluate the nature and extent of groundwater contamination, and provide sufficient data to perform a risk assessment. Table 2-2 outlined the sample location relationship by showing the correlation of groundwater sampling wells to potential source areas in Northern Bush River.

GP collected 38 groundwater samples and eight duplicates from two rounds of sampling for chemical analysis in accordance with SOP 013 of Appendix J to the Generic Work Plan. Sampling teams purged and sampled all monitoring wells using low-flow submersible pumps. To ensure a representative groundwater sample of the aquifer, the field team monitored seven chemical and physical water quality parameters (i.e., pH, temperature, conductivity, dissolved oxygen, oxidation/reduction potential, salinity, and turbidity) at the well site to determine when to collect the sample. When these parameters were stable, the sample was collected. The

Table 2-3. Northern Bush River RI Program Media Sampling Events and Quality Assurance/Quality Control Summary

Performer	Sample Media	Sample Designation	Type & Number of QA/QC Samples Per Round of Sampling	
			Round 1	Round 2
General Physics Corporation	Groundwater	WBR-11 to WBR-13, WBR-15 (Bio-Sensor Facility)	05/28/96 to 05/29/96	08/26/96 to 08/27/96
			Trip Blanks -2	Trip Blanks -2
		WBR-76, WBR-81 to WBR-84, WBR-86 to WBR-88 (Bush River Storage Areas)	Duplicates -1	Duplicates -1
			Field Blanks -1	Field Blanks -1
			Rinsate Blanks -1	Rinsate Blanks -1
		WBR-70, WBR-74, WBR-75, WBR-77 to WBR-80 (Warehouse Sites)	01/04/95 to 01/20/95	05/01/95 to 05/04/95
			Trip Blanks -5	Trip Blanks -3
	Surface Water	C07-SW-01 to C07-SW-05	Duplicates -1	Duplicates -1
			Field Blanks -1	Field Blanks -1
		C35-SW-01 to C35-SW-04	Rinsate Blanks -1	Rinsate Blanks -1
		C36-SW-01 to C36-SW-04	02/08/95 to 02/15/95	06/05/95 to 06/08/95
			Trip Blanks -6	Trip Blanks -4
			Duplicates -2	Duplicates -2
			Field Blanks -2	Field Blanks -2
			Rinsate Blanks -2	Rinsate Blanks -2
			05/22/96	08/28/96
			Trip Blanks -1	Trip Blanks -1
			Duplicates -1	Duplicates -1
			Field Blanks -1	Field Blanks -1
			Rinsate Blanks -1	Rinsate Blanks -1
			01/12/95	05/15/95
			Trip Blanks -1	Trip Blanks -1
			Duplicates -1	Duplicates -1
			Field Blanks -1	Field Blanks -1
			Rinsate Blanks -1	Rinsate Blanks -1
			03/17/95	06/12/95, 06/20/95
			Trip Blanks -1	Trip Blanks -1
			Duplicates -1	Duplicates -1
			Field Blanks -1	Field Blanks -1
			Rinsate Blanks -1	Rinsate Blanks -1

Table 2-3. Northern Bush River RI Program Media Sampling Events and Quality Assurance/Quality Control Summary (continued)

Performer	Sample Media	Sample Designation	Type & Number of QA/QC Samples Per Round of Sampling	
			Round 1	Round 2
General Physics Corporation (Continued)	Sediment	C07-SD-01 to C07-SD-05	05/22/96 (Agent Screening) 06/10/96 Trip Blanks -1 Duplicates -1 Field Blanks -1 Rinsate Blanks -1	
			01/12/95 (Agent Screening)	03/24/95, 05/15/95 (No QA/QC Samples)
		C36-SD-01 to C36-SD-04	03/17/95 (Agent Screening)	06/12/95, 06/20/95 Trip Blanks -1 Duplicates -1 Field Blanks -1 Rinsate Blanks -1
	Surface Soil	C07-SS-04 to C07-SS-07, C07-SS-14 to C07-SS-16	05/23/96, 05/24/96 (Agent Screening) 06/10/96, 06/11/96 Trip Blanks -2 Duplicates -1 Field Blanks -1 Rinsate Blanks -1	
			01/11/95 (Agent Screening)	05/09/95 Trip Blanks -1 Duplicates -2 Field Blanks -2 Rinsate Blanks -2
		C35-SS-01 to C35-SS-14		06/12/95, 06/13/95, 06/16/95 Trip Blanks -2 Duplicates -2 Field Blanks -2 Rinsate Blanks -2

Table 2-3. Northern Bush River RI Program Media Sampling Events and Quality Assurance/Quality Control Summary (continued)

Performer	Sample Media	Sample Designation	Type & Number of QA/QC Samples Per Round of Sampling	
			Round 1	Round 2
			05/23/96, 05/24/96 (Agent Screening)	
General Physics Corporation (Continued)	Subsurface Soil	C07-SO-01 to C07-SO-03, C07-SO-08, C07-SO-10 to C07-SO-13	06/10/96 to 06/12/96	
			Trip Blanks	- 2
			Duplicates	- 1
			Field Blanks	- 1
			Rinsate Blanks	- 1
	Sludge	C07-SL-09	06/10/96	
			Trip Blanks	- 1
		C36-SL-11		06/14/95
				Trip Blanks
				- 1

WBR=Bush River Monitoring Well
 SW=Surface Water
 SD=Sediment
 SS=Surface Soil

SO=Subsurface Soil
 SL=Sludge
 C07=Cluster 7
 C35=Cluster 35

C36=Cluster 36
 QA/QC=Quality Assurance/Quality Control

parameters are considered stable when the measurements deviate less than 10 percent over three consecutive readings. The RI Sampling and Analysis Reports for Northern Bush River present the details of the groundwater sampling (GP, 1995b through d and 1996; Earth Tech, Inc and GP, 1996b).

General Physics Environmental Services analyzed the groundwater samples for the presence of analytes found on the Target Compound List (TCL) and Target Analyte List (TAL), explosive-related compounds, chemical agent degradation products, general chemical constituents and physical properties, and radiological parameters. Solutions To Environmental Problems, Inc., (STEP) validated the groundwater data (STEP, 1996a through d). Table 2-3 also presented the type and number of field QA/QC samples collected per round of groundwater sampling. All sample containers were labeled, secured, preserved, and shipped in accordance with SOPs 001, 002, 039, and 004 of Appendix J to the Generic Work Plan. Table 2-4 lists the analytical parameters and methods used during the RI groundwater sampling program. Section 4 summarizes analytical results of the groundwater sampling.

2.6 Surface Water and Sediment Investigations

As part of the Northern Bush River RI program, GP collected two rounds of surface water samples at 13 locations and one round of sediment samples at 14 locations for chemical analysis at designated dates between January 1995 and August 1996. Figure 2-3 illustrates the surface water and sediment sampling locations. Table 2-3 presented the dates of each surface water and sediment sampling event, and the sample locations associated with each event. The primary purpose for collecting these samples was to evaluate surface water and sediment quality in the tributaries of Lauderick Creek and Kings Creek, determine the distribution and concentrations of contaminants from upgradient, potential source areas, and provide sufficient data to perform a risk assessment. Accordingly, GP collected surface water and sediment samples from the near-shore marsh areas of Lauderick Creek and Kings Creek at locations north, south, east, and west of Northern Bush River sites (Figure 2-3). Table 2-5 outlines the sample location relationship by showing the correlation of surface water and sediment sampling points to potential source areas in Northern Bush River.

2.6.1 Surface Water and Sediment Sampling and Analysis

GP collected 26 surface water samples and six duplicates from the two rounds of sampling for chemical analysis in accordance with SOP 007 of Appendix J to the Generic Work Plan. The field sample teams recorded water quality parameters for pH, temperature, conductivity, dissolved oxygen, oxidation/reduction potential, salinity, and turbidity from the vicinity of surface water collection at the time of sampling. GP collected 14 sediment samples and two duplicates from the

Table 2-4. Northern Bush River RI Program Analytical Parameters and Methods

Parameter	Matrix	Method
Target Compound List		
Volatile Organic Compounds	Water/Solids	CLP-OLM01.8
Semivolatile Organic Compounds	Water/Solids	CLP-OLM01.8
Pesticides/Polychlorinated biphenyls	Water/Solids	CLP-OLM01.8
Target Analyte List		
Metals, Total	Water/Solids	CLP-ILM03.0
Metals, Dissolved	Water	CLP-ILM03.0
Cyanide, Total	Water/Solids	CLP-ILM03.0
Explosive related compounds	Water/Solids	SW-846 8330
Radiological Analysis		
Gross Alpha Radioactivity	Water/Solids	EPA-600 900.0
Gross Beta Radioactivity	Water/Solids	EPA-600 900.0
Gamma Spectral Analysis	Solids ¹	EPA-600 901.1
Chemical Agent Degradation Products		
Organosulfur Compounds	Water/Solids	USAEC- UL04/LL03
Thiodiglycol	Water/Solids	USAEC- UW22/LW18
Chloroacetophenone and Degradation Compounds	Water/Solids	SW-846-8270
Methyphosphonic Acid (MPA) /Isopropylmethylphosphonic Acid (IMPA)	Water/Solids	USAEC- UT02/AAA9
Dimethylmethylphosphonate (DMMP) /Diisopropylmethylphosphonate (DIMP)	Water/Solids	USAEC- T8M /TT9
General Wet Chemicals		
Phenols Total	Water	EPA-600 420.1
	Solids	SW-846 9066
Phosphorus, Total	Water	EPA-600 365.2 or 365.1
	Solids	SW-846 365.2
Bicarbonate	Groundwater	EPA-600 310.1
Chloride	Groundwater	EPA-600 325.2 or 325.3